IMAGE INTERPRETATION AND COMPARISON OF CLASSIFIED MSS AND TM DATA

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by
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CERTIFICATE

This is to certify that present work entitled, "IMAGE INTERPRETATION AND COMPARISON OF CLASSIFIED MSS AND TM DATA" has been carried out by Mr. Kishor Kumar Pahuja under my supervision and is not produced anywhere for the award of a degree.

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-K.K.Pahuja

CONTENTS

SUMMARY

The analysis of remote sensing data is very important in mapping surface and subsurface features.The knowledge of these features is helpful in estimating country's hidden resourses. The LANDSAT MSS and TM data are available from National Remote Sensing Agency, Hyderabad. In the present work ,we have analysed MSS and TM data using image processing technique. The classified image has been compared with the toposheet prepared in the year 1976 by Survey of India. The various surface features such as river, roads, railway lines ,soils, vegetated cover, forest areas, water bodies and built-up areas are classified using MSS and TM data. The information about a scene using MSS data is more because of larger area covered. However the resolution of the image obtained by TM data is higher compared to that of MSS imagery. We have taken remote sensing data of path number 144, row number 41 of MSS and quadrant 'D' of data and carried out digital analysis using Bayes technique and compared the results. We have found that both the data have their own limitations in mapping various surfacial features. The detailed analysis and superiority of these data has been discussed in the present work.

CHAPTER I

INTRODUCTION

1.1 Concept of Remote Sensing

The art of remote sensing started with the objective of locating the enemy camps and strategic locations. Remote sensing means getting the information about an object without coming in physical contact with it. This technique is based on the electromagnetic energy either reflected or emitted from the object. The wavelength range can be in visible, in the infrared or in the microwave range of electromagnetic spectrum. The components of a basic remote sensing system are shown in Fig.(1.1). Conventional remote sensing uses the reflected energy in visible and infrared range in which sensors are used to detect the incoming energy from the object. The technique has been used in a wide range of problems. Large data handling is made possible by the expanding computer network in different countries. The visual interpretation, assisted by aerial photos has been used as a complementary method. Amongst the satellite data available for the users, SPOT data look very promising giving 20m resolution in the MSS mode and 10m in the panchromatic mode. Landsat-6 to be launched in near future is expected to

carry enhanced thematic mapper (ETM). This shall incorporate additional band in the "panchromatic" band(0.5 to 0.86 μ m) having ground resolution of 15m. Sometimes the sensor is equipped to send the energy towards the object and getting the reflected energy. This type of sensing is known as active remote sensing and example is Radar. Radar sensors operate in the microwave frequency range (i.e.0.3 to 300 GHz or 1 mm to 1m. range of wavelength) of electromagnetic spectrum. Microwave sensing also uses passive sensors like the microwave radiometers. Microwave sensors have the advantage of penetrating the atmosphere during day and night and also they can penetrate deeper in the ground. The common forms of microwave sensing are side looking airborne radar (SLAR), plan position indicator (PPI) and synthetic aperture radar (SAR). SLAR has been used for military reconnaissance. It has also been used for mapping the terrain in various countries, water resources and to prepare the geologic maps. Radar imagery has been used for the mapping of vegetation and crop identification in various countries.

1.2 Remote Sensing Today

Starting from 1960, remote sensing now is being used in almost all the branches of physical sciences. The major areas of application being geography, geology, civil engineering, forestry, meteorology, agriculture and oceanography. July 1972 saw the launching of the first remote sensing satellite namely ERTS-1 by United States of America and subsequently

the availability of data products in various countries assumed the future of the newly developing techniques. Since 1972, five such satellites have been sent for the purpose by United States of America , the latest being Landsat 5 (D'). SPOT, a remote sensing satellite of France became operational from 1985 giving resolution of as low as 20 m.

India has now joined the select band by sending IRS-1A (Indian Remote Sensing Satellite). The sensors work in the multi spectral scanner (MSS) mode to get the data in four bands. The details of IRS-1A are given in table 1.1.

1.3 Remote Sensing Systems

Figure (1.1) shows the basic elements of a remote sensing system. The main component of the system is the sensor which can be even a photographic camera for the simplest of cases. At present the data is being collected by Landsat-5 of Landsat series. SPOT is also operational from 1985. The orbital characteristics of Landsat-4 and-5 are given below:

(i) Sunsynchronus orbit.

(ii) Pass at the equator of each orbit at 9.45 am. local sun time.

iii) Near polar orbit, inclination of 98.2° with respect to the equator.

iv) Altitude of 705 km.

v) Repeat day period of 16 days.

Table 1.1 Indian Remote Sensing Satellite (IRS-1A)

Objectives of Mission – To provide agricultural, geological and hydrologica data for survey and management of natura resources

Orbit Characteristics – Sunsynchronus, 904 km. altitude and having 22 da repeat cycle.

Sensor	Applications	Number of Channels	Spectral Range(μm)	Resolution (m)	Swath (Km)
LISS-I (Linear Imaging Self Scanning Sensor)	Landuse,urban planning,mapping, agriculture,water resources,forestry, geological and mineral resources	4	0.45-0.86	73	148
LISS-II	-do-	4	0.45-0.86	36	148

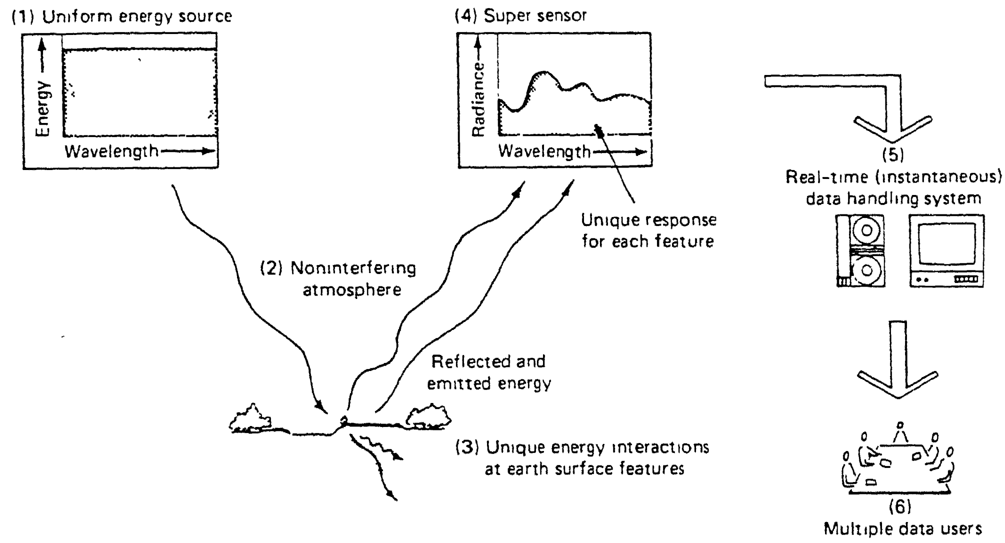

Fig. 1.1 Components of a basic Remote Sensing System

(Lillesland and Kiefer 1985)

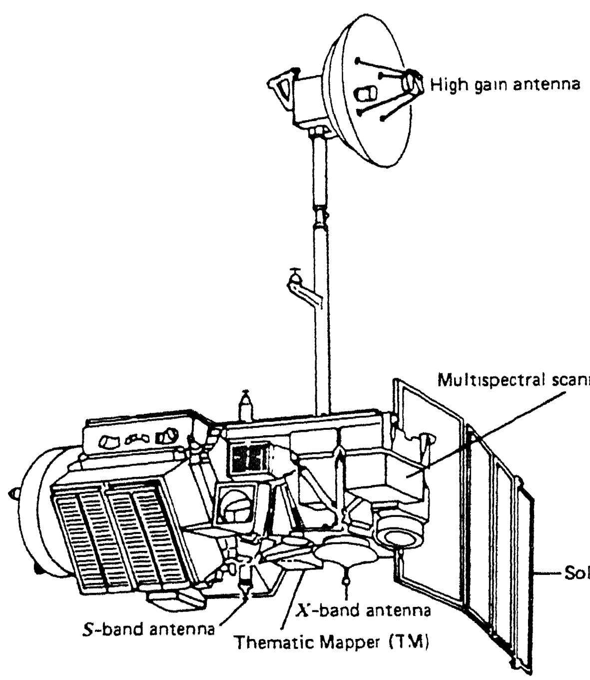

Fig. 1.2 Sensors Onboard Landsat-4

(Lillesland and Kiefer 1985)

The satellite collects the data by the following sensors-

(i) Return Beam Vidicon

(ii) Multi spectral scanner

(iii)Thematic mapper.

Sensors onboard Landsat are shown in Fig. (1.2).

The details of the MSS mode and thematic mapper are given in Tables 1.2 and 1.3 respectively. Details of SPOT satellite system are given in Table 1.4

1.4 Remote Sensing in Civil Engineering

The application of remote sensing extends right from the terrain investigation to urban planning, in water resources, environmental studies,and a host of other aspects in which it acts as an aid to the more conventional methods.

The remote sensing methods are highly cost effective means to get up-to-date and repetitive information, Route mapping for highway location and design has been one of the most common projects in civil engineering. Application of remote sensing for site investigation emphasises on locating the features of geotechnical significance. Remote

Table 1.2 MSS Bands

Landsat MSS Band No.		Band Width (μm)	Wave Band Name
Landsat 1,2 & 3	Landsat 4 & 5 5(D')		
4	1	0.5–0.6	Green
5	2	0.6–0.7	Red
6	3	0.7–0.8	Near Infrared
7	4	0.8–1.1	Near Infrared

Table 1.3 Thematic Mapper Bands

Band No.	Band Name	Band Width (μm)	Characteristics
1	Blue/Green	0.45–0.52	Good water penetration strong vegetation absorbance
2	Green	0.52–0.60	Strong vegetation reflectance
3	Red	0.63–0.69	Very strong vegetation absorbance
4	Near Infrared	0.76–0.90	High land-water contrasts,very strong vegetation reflectance
5	Near-middle Infrared	1.55–1.75	Very mositure sensi- tive, effect of snow and clouds
6	Thermal Infrared	10.4–12	Very sensitive to soil moisture and vegetation
7	Middle Infrared	2.08–2.35	Good geological discrimination

Table 1.4 SPOT Satellite System Specifications

Orbital Details

Altitude (km.)	832
Period (min)	101
Equatorial spacing of orbits (km.)	1084
Number of orbits/day	14.2
Number of days for repeat coverage	26
Equator crossing time	10.30
Swath width (km)	60

Sensor Details

High Resolution Visible (HRV) Scanner-

MSS mode -

Number of spectral bands	3
Spectral ranges (μm)	0.50-0.59
	0.61-0.68
	0.79-0.89
Number of individual sensor detectors	3000
Ground Resolution	20m
Number of grey levels	256/(8 bit)
Date rate (mega bits/s)	25

Black and white mode -

Number of spectral bands	1
Spectral range (μm)	0.51-0.73
Number of individual sensor detectors	6000
Ground resolution	10m
Number of grey levels	128 (6 bit)
Date rate (mega bits/sec)	25

sensing plays important role in environmental engineering which includes its use in the study of the thermal and chemical pollution. Use of remote sensing in the studies of soil units is well established. Remote sensing in geology is used to give information on structure and lithology of rocks and features like folding,faulting etc. Black and white, and colour infrared photographs have been used to map crops, crop growth etc.

In the hydrological application surface and subsurface water sources can be inferred from the study of channels, lakes, drainage patterns etc. These features can be used detect ground water, which is indirectly inferred with the use of remote sensing. Other areas of study include flood and wetland studies. In areas of irrigation, large differences of soil moisture could be delineated to know the water use and stress on the crops. Areas of recent rainfall are detected in semi arid and arid regions. Another important area in which the remote sensing has been applied is in the distribution of snow fields and the likely volume of water from their melt.

CHAPTER II

FUNDAMENTALS OF ANALYSIS

This chapter covers the properties of the cover surfaces and the reflectance response produced by different land cover types. A general description of pattern recognition techniques and the classifiers to extract useful information has been covered. Broad ideas of digital image processing and its usefulness in feature extraction is given in this chapter.

2.1 Reflectance from Cover Surfaces

A graph of the spectral reflectance of an object as a function of wavelength is termed as spectral reflectance curve. The configuration of spectral reflectance curve gives insight into the spectral characteristics of an object and dictates the choice of the wavelength region(s) in which remote sensing data are required for particular application. The presence of peaks and lows in the reflectance curve of a particular type of feature characterise one surface from others. The spectral responses measured by remote sensing sensors permit an assessment of the type and/or condition of the surface features, and hence called spectral signatures.

Typical reflectance curves for vegetation, soil and water are shown in Fig. (2.1) In case of water the most distinctive characteristic is the energy absorption in near infrared wavelengths. The reflectance properties of water bodies are modified by other factors such as sediments, bio-mass etc. The reflectance decreases with the increase in depth of water bodies in the near infrared wavelengths. Water containing large quantities of suspended sediments resulting from soil erosion normally have much higher visible reflectance than clear waters. The effect of increase in chlorophyll concentration is seen in blue wavelength where reflectance decreases. These features can be used to estimate the concentration of algae, presence of tanning dyes and the detection of a number of pollutants.

Vegetation gives lower reflectance in range of 0.45 and 0.67 μm due to the pigment in the plant leaves. In the near infrared (0.70 to 0.8 μm) the reflectance of healthy vegetation increases dramatically. Plant reflectance in the range of 0.70 to 1.3 μm results from the internal structure of plant leaves. Since the structure is highly variable between plant species, reflectance measurements in this range help to discriminate between different types. Leaf reflection is inversely related to the total water present in a leaf. Reflectance is also controlled by the thickness of a leaf.

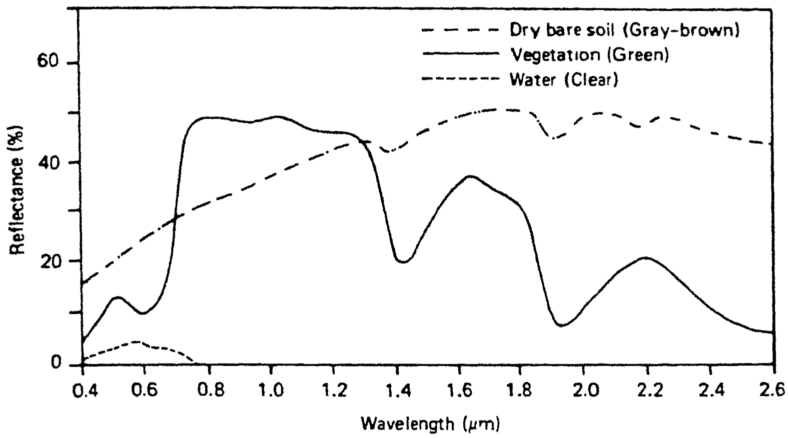

Fig. 2.1 Typical Reflectance Curves for Water Soil and Vegitation

(Paul J. Curran 1985)

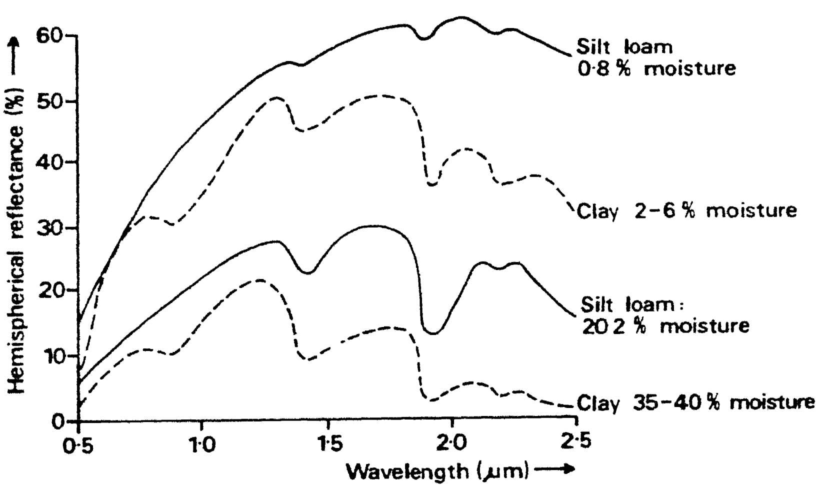

Fig. 2.2 Reflectance Curves for Soils

(Paul J. Curran 1985)

Reflectance from soil is a function of particle size, texture, mineral composition, organic content, moisture content and temperature. Clay soils have strong structure in terms of packing and high moisture content, and hence give fairly low reflectance (presence of organic content also reduces the reflectance). Sandy soils on the other hand have a weak structure and present a fairly smooth surface and low moisture content and hence fairly high and often specular reflectance properties. In the visible wavelengths the presence of soil moisture considerably reduces the surface reflectance of soil. The same is true in near and middle infrared wavelengths also. Soil organic matter is dark and its presence decreases the reflectance from the soil upto organic content of 4-5%. For greater organic content further decrease in the reflectance is not appreciable.

One peculiar characteristic of soils is their association with vegetation. Often a particular type of soil is associated with a particular typ of vegetation. Also the extent of cover and the nature of vegetative cover (fully developed or less developed) affects the soil reflectance.

The effect of vegetation can be in the following ways-

(a) due to shadow of vegetation

(b) due to partial cover and

(c) due to change in organic content and moisture content brought out by vegetative cover.

The reflectance curves for soils are shown in Fig. (2.2).

2.2 Pattern Recognition and Classification

The remote sensing data is full of surface and subsurface information. This information is only extracted when analyse and interpret the data accurately. The analysis and interpretation is carried out by using pattern recognition and classification technique which is carried out either with visual interpretation or with computer. Visual interpretation involves the human experience and skill and the accuracy in the interpretation depends on the interpreter. The qualitative aspects of visual interpretation are -

(i) Tone - In the satellite imagery there is variation of tone or shades, depending on the radiation reflected from different surfaces. It is expressed as light, medium and dark.

(ii) Texture - This is defined as therate of change of tonal values, generally classified as coarse, medium and fine.

(iii) Size - Depending on the scale of the imagery available, relative difference can be identified.

(iv) Shape - Different ground features have different shapes due to structure and topography which can be identified from the imagery.

(v) Shadow- Shadows, cast particularly by the tall objects are used for the identification.

(vi) Association- Some features on the imagery can not be directly identified as such but due to association with particular features their presence is indirectly inferred.

(vii) Pattern - Pattern is the spatial arrangement of various types of features. The arrangements can be in different forms. Geological patterns are either linear or curved depending on the geological features such as faults, joints, folds etc. The topographical pattern is related to various types of drainage patterns (Fig.2.3). The drainage pattern and texture seen on any imagery are indicators of landform and type of bedrock and soil. The dendritic drainage pattern is a well integrated pattern formed by main stream with its tributaries branching and rebranching in all directions. The trellis pattern has one dominant direction and tributaries at right angles to it. The radial pattern is typical of volcanoes and domes. Anastomatic pattern with its meandering streams, cut-off meanders and ox-bow lakes is typical of the alluvial terrain.

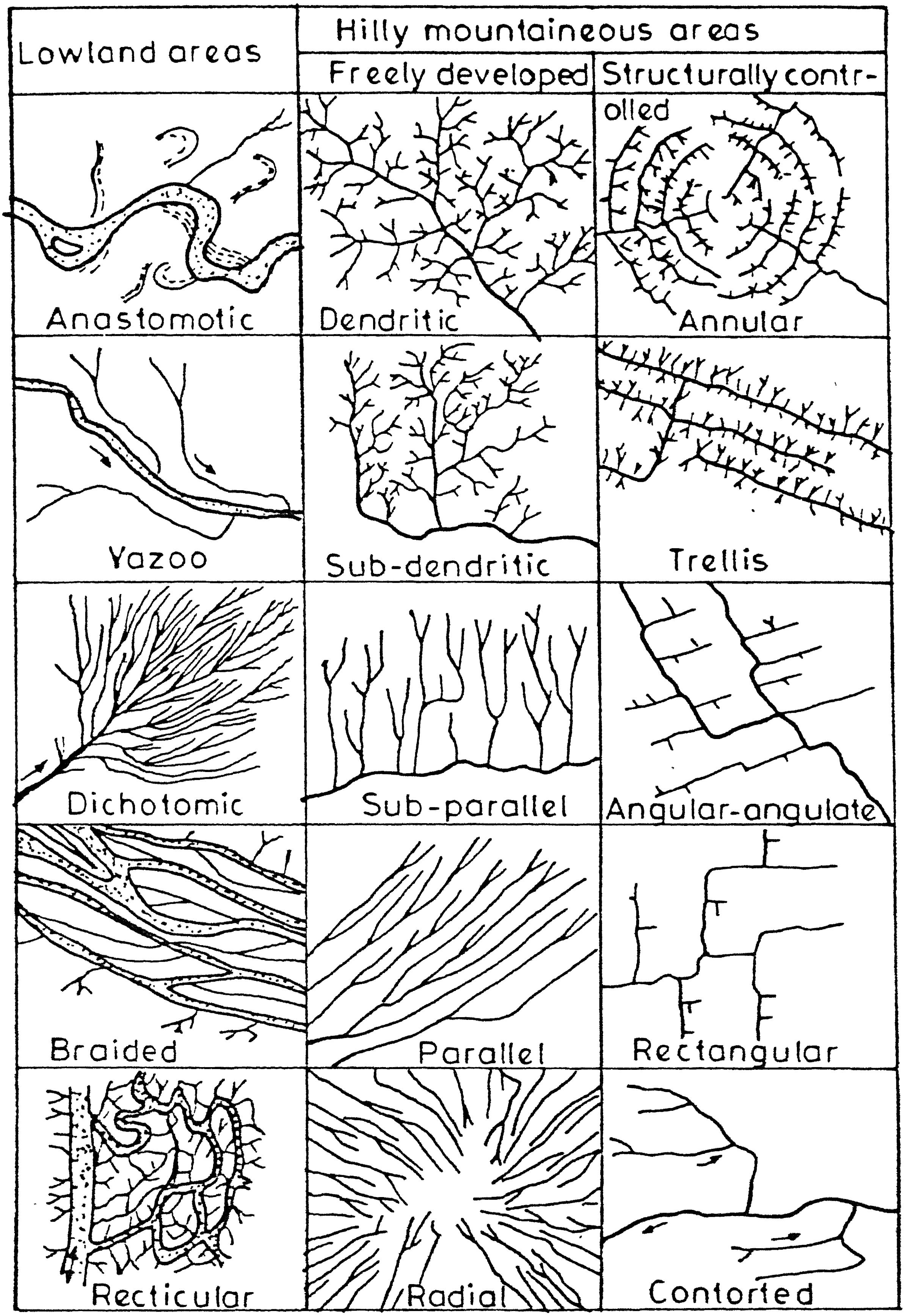

Fig. 2.3 Drainage Patterns

2.3 Computer Aided Analysis and Digital Image Processing

The interpretation of the remotely sensed data involves large data to be handled to get the useful information and hence the visual interpretation becomes difficult. Image classification using computer, automatically categorizes all the pixels in an image into number of classes which can be used to represent various themes of land cover. spatial pattern recognition the categorization of image pixels is done depending on the spatial relationship with surrounding pixels. The temporal pattern recognition of a scene can be used as an aid in feature identification. Image classification can be either supervised or unsupervised.

Basic steps in the supervised classification are shown in Fig.(2.4). In the training stage, sets of spectral data is collected to determine decision rules for the classification. In the classification stage each pixel in the image data is categorized into the land cover class in which there is resemblance. After the categorization, the results are presented in the output stage. The unsupervised classifier does not utilize training data as the basis of classification and hence stage I is absent.

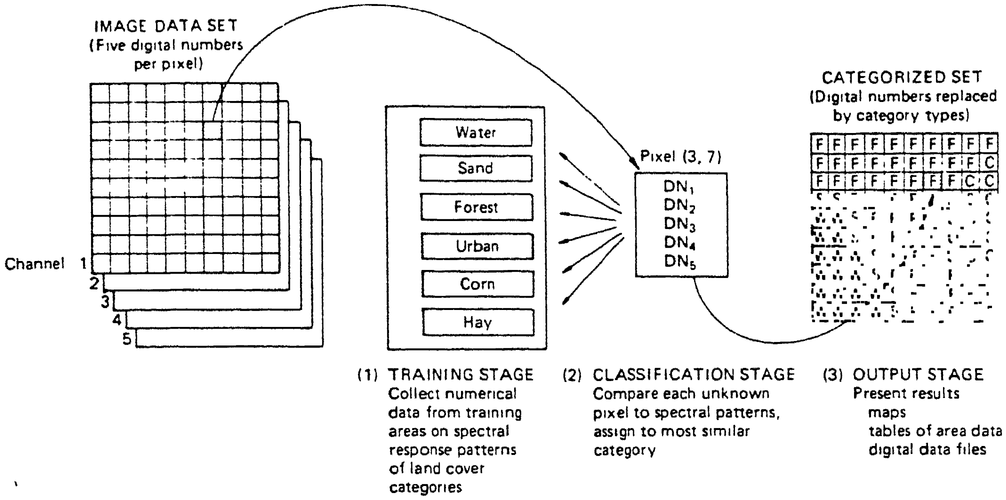

Fig. 2.4 Steps in Supervised Classification

(Lillesland and Kiefer 1985)

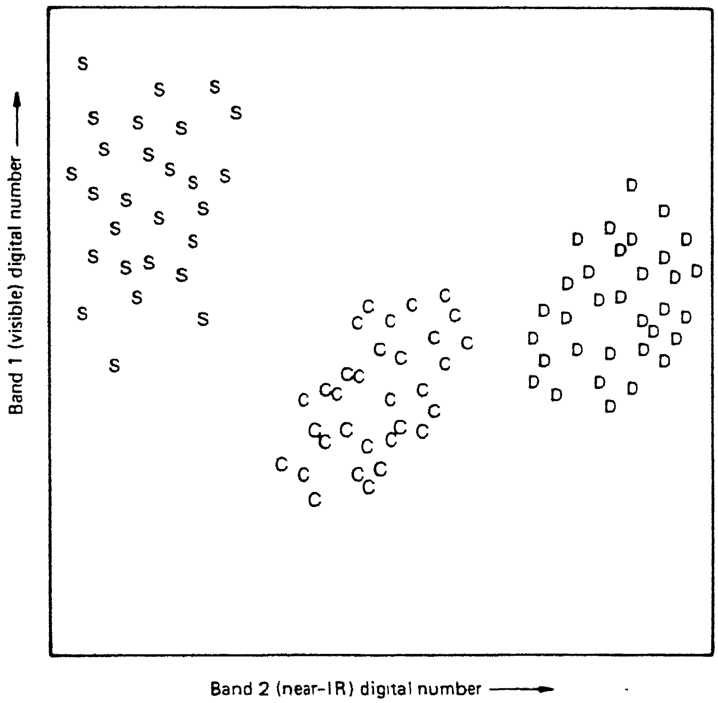

Fig. 2.5 Two Band Clustering of data

(Lillesland and Kiefer 1985)

2.4 Unsupervised Classification

The basic requirement for using such classifiers is that the different classes should be comparatively well separated. As a result of classification, analyst gets different spectral classes. These classified data have to be compared to some form of reference data to determine identity of spectral classes. The major advantage of such classifiers is that many of the classified classes might not be initially apparent to the analyst applying supervised classifier. When the spectral classes are too many it is advantageous to use such classifiers. The clustering algorithms may use 2 (Fig.2.5) or 4 channel data. K-class classifier is one such approach. In the present study, mode seeking algorithm has been used.

2.5 Mode Seeking Algorithm

Clusters are the homogeneous groups developed by the concentration of observation data around a point, called cluster centre. Any observation is assigned to the cluster only when the distance to the cluster centre is less than or equal to cluster threshold. In case when many cluster centres exist within the cluster threshold, the observation is assigned to the cluster with the closest centre. Due to the constant accretion in any cluster ~~the cluster~~, the cluster

centre is also modified. The step-wise procedure is as follows-

(i) First data point is taken as the centre of first cluster.

(ii) Calculate the square of the distance between the next data point and the first cluster centre.

(iii) If the value so found is less than or equal to the cluster threshold then the point is assigned to the first cluster.

(iv) If not, a new cluster with the above point originates.

(v) With any data point the square of the distance of the data point with all the cluster centres is calculated and smallest of these values is chosen. If the selected distance is less than or equal to the cluster threshold the observation data is allotted to the nearest cluster.

(vi) Grade which represents the members present in the cluster is constantly upgraded.

The flow chart for the algorithm used, is given in Fig.(2.6).

2.6 Supervised Classification

To select the training data set for the supervised classifier complete knowledge of the geographic area is necessary. The quality and accuracy of the training data controls the accuracy of classification and hence

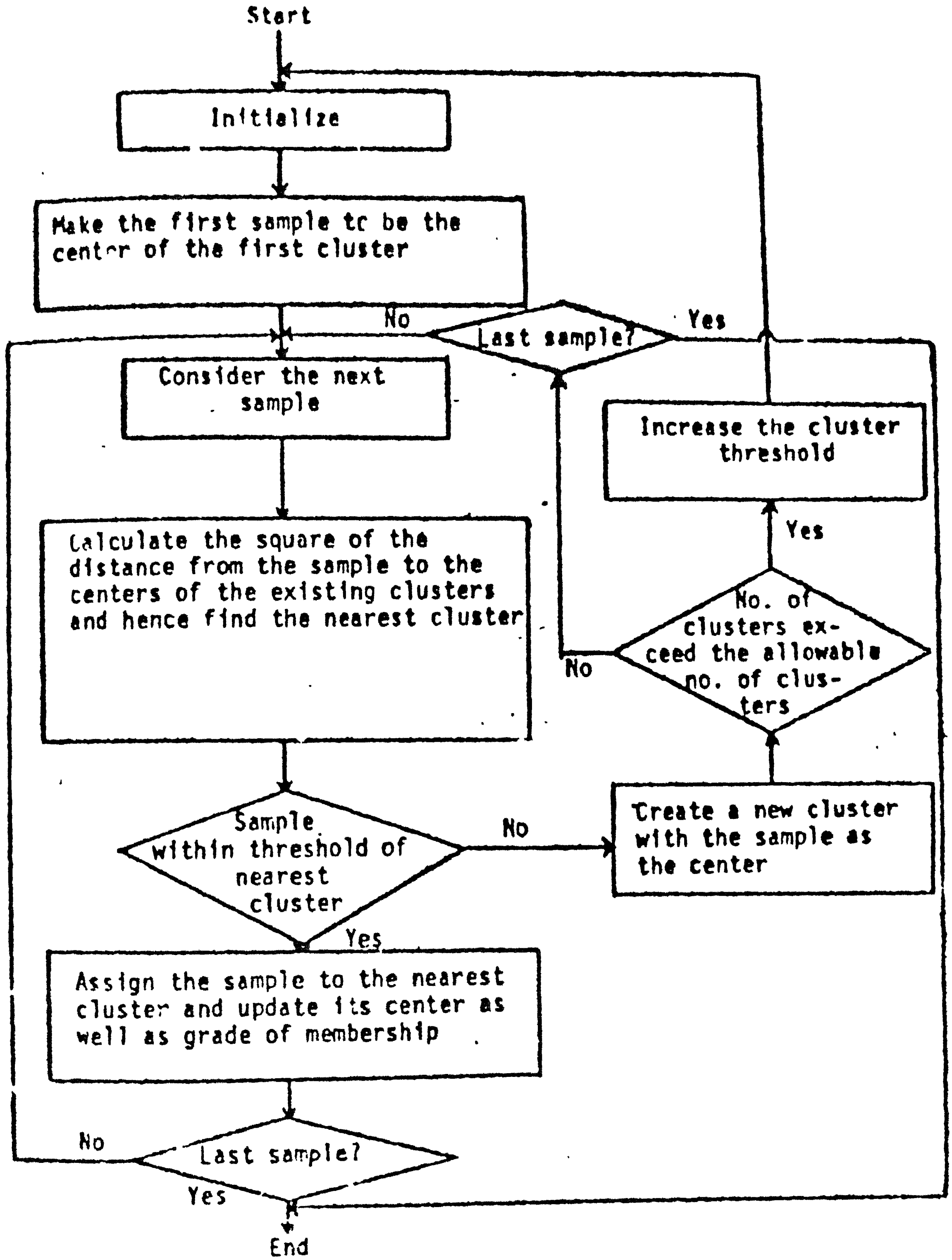

Fig. 2.6 Flow Chart for Mode Seeking Algorithm

interpretation of image. The training data set has to be truly representative of the area. Sometimes two spectral classes might be required to adequately train a feature with large variation in spectral characteristics.In order to evaluate the training data, self classification of the training data is done to detect errors in the data.

In the classification stage, actual classsification of the test sample is performed using mathematical and statistical appropaches. It is possible to use 2 or 4 channel data of MSS. Bayes decision rule is used for the classification purpose. This is an extension of maximum likelihood approach. The approach evaluates both the variance and covariance of the category spectral response patterns. The distribution for the clouds of points constituting a category is assumed Gaussian. With this assumption distribution of response pattern of any category can be completely described by the mean vector and the covariance matrix. Statistical probability is calculated of a given pixel being a member of a particular category. The resulting probability density functions are shown in Fig.(2.7). Probability of each pixel is checked and the pixels are assigned to the most likely class. In the Bayes decision the probability of misclassification is calculated for each category by assigning a "priori probability" for each class and assigning a weight associated with the error of misclassification.

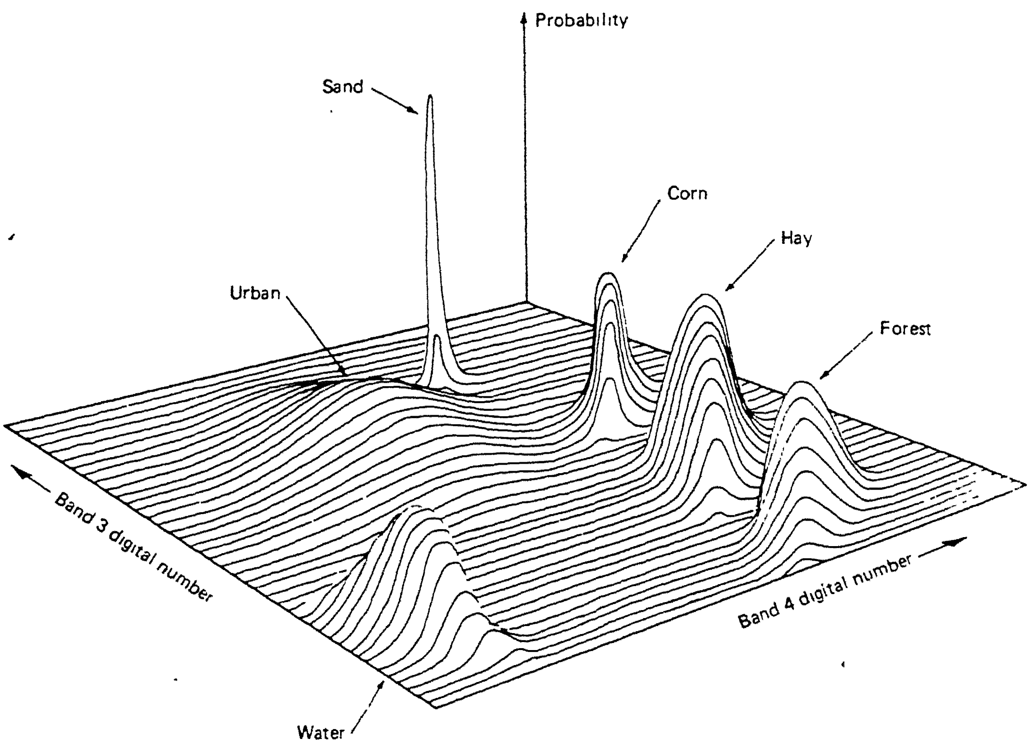

Fig. 2.7 Probability Density Functions

(Lillealand and Kiefer 1985)

2.7 Bayes Decision

Any measurment 'X' is assigned to the class G, with the highest conditional probability,minimizing the total error of classification. Amongst the G group or classes measurment 'X' is assigned to group i if-

$$P(G_i/X) > P(G_i/X) \text{ for all } i \neq j$$

where $P(G_i)$= Probability of class "i"

and $P(G_j)$= Probability of class "j".

The final form of Bayes rule is

$$P(X/G_i)\ P(G_i) > P(X/G_j)\ P(G_j) \text{ for all } j \neq i$$

To apply the Bayes rule we have to use the value of $P(G_i)$ and $P(X/G_i)$ for each group. Now assuming that within each group the varibles that make up the measurment vector X have a multivariate normal distribution,the form of conditional probability $P(X/G_i)$ becomes

$$P(X/G_i)=\frac{1}{(2\pi)^{n/2}|\Sigma_i|^{1/2}} \exp\left(\frac{-1}{2}(X-\mu_i)\Sigma^{-1}(X-\mu_i)\right)$$

where μ_i= mean of class or group 'i'

Σ_i= variance covariance matrix of class 'i'

and $P(G_i)$= A priori probability of class 'i'.

Hence the estimation of $P(X/G_i)$ becomes calculating the parameters, μ_i the group mean vector and Σ_i the group covariance matrix. If there are n measurments in X (n bands) then there are 'n' group means in the mean vector and $\frac{n(n+1)}{2}$ elements in the covariance matrix making a total of $\frac{n^2+3n}{2}$

quantities to be estimated for each group, but this is considerably less than the number of estimations required for a direct application of the Bayes rule.

Using the normal form of $P(X/G_i)$ we have

Assign X to G_i if–

$$\frac{P(G_i)}{(2\pi)^{1/2}|\Sigma_i|^{1/2}} \exp\left[\frac{-1}{2}(X-\mu_i)\Sigma_i^{-1}(X-\mu_i)^T\right] >$$

$$\frac{P(G_i)}{(2\pi)^{n/2}|\Sigma_j|^{n/2}} \exp\left[\frac{-1}{2}(X-\mu_j)\Sigma_j^{-1}(X-\mu_j)^T\right]$$

for all $i \neq j$

Taking the normal log(ln) of both sides

$$\frac{-1}{2} n \ln(2\pi) \frac{-1}{2} \ln|\Sigma_i| \frac{-1}{2} (X-\mu_i)\Sigma_i^{-1}(X-\mu_i)^T + \ln P(G_i) >$$

$$\frac{-1}{2} n \ln(2\pi) \frac{-1}{2} \ln|\Sigma_j| \frac{-1}{2} (X-\mu_j)\Sigma_j^{-1}(X-\mu_j)^T + \ln P(G_j)$$

for all $i \neq j$

Cancelling the common terms,

$$-\ln|\Sigma_i| - (X-\mu_i)\Sigma_i^{-1}(X-\mu_i)^T + \ln P(G_i) >$$

$$\ln|\Sigma_j| - (X-\mu_j)\Sigma_j^{-1}(X-\mu_j)^T + \ln P(G_j)$$

for all $i \neq j$

$$\rightarrow \ln|\Sigma_i| + (X-\mu_i)\Sigma_i^{-1}(X-\mu_i)^T - \ln P(G_i) <$$

$$\ln|\Sigma_j| + (X-\mu_j)\Sigma_j^{-1}(X-\mu_j)^T - \ln P(G_j)$$

for all $j \neq i$

The quantity $\ln|\Sigma_i| + (X-\mu_i)\Sigma_i^{-1}(X-\mu_i)^T - \ln P(G_i)$ is referred to as "Discriminant Score" and

$d_i(X) = \ln|\Sigma_i| + (X-\mu_i)\Sigma_i^{-1}(X-\mu_i)^{1/2}$ is called "Discriminant Function".

As a final rule of Bayes decision, assign the measurement'X' to the group with the smallest value of $d_i(X)-\ln P(G_i)$.
Hence, assign 'X' to group i if-

$$d_i(X)-\ln P(G_i) < d_j(X)-\ln P(G_j) \text{ for all } j\neq i.$$

X is multivariate normally distributed in each of the classes.

Maximum likelihood Bayes classsifier is the most efficient classifier for categorization of the image pixels. For further study it is proposed that the urban area from the scene could be zoomed to get more detailed information.

For the detailed vegetation analysis Kauth and Thomas(ref.4) have derived a linear transformation using four bands of landsat MSS. Crist and Cicone(ref.4) extended the same concept to Landsat TM data. For vegetation analysis and crop identtification three indices have been defined which are mathematically expressed as (Lillesand and Kiefer, 1985).

(i) Vegetation Index (VI) = DN2 − DN1

(ii) Normalized Vegetation Index (NVI) = $\frac{DN2-DN1}{DN2+DN1}$

where DN2 is reflectance value in near infrared band and DN1 is the reflectance value in visible band (i.e. 0.58 to 0.68μm)

(iii) Transformed Vegetation Index(TVI) $= \left[\dfrac{DN4-DN3}{DN4+DN3} + 0.5 \right]^{1/2} \times 100$

Here DN3 and DN4 are the reflectance values in band 3 and band 4 of TM.

Vegetated areas invariably give high value of TVI. Programme to compute the TVI for the whole scene to generated the TVI image is given (Index.fort).Using this programme as many as six vegetation categories can be analysed.

2.8 Digital Interactive Image Processing

Digital image processing encompasses a wide variety of techniques and mathematical tools. A digital image is accepted as input and the image in some aspects is enhanced with image enhancement process. Image enhancement includes manipulating contrast, removing geometric distortion, edge smoothing and sharpening etc. A standard imagery is a general purpose product and cannot be controlled in a way users like hydrologists, geologists and urban planners desire. Digital images in the other hand can be made to fit for the specific purposes. To make the feature extraction easier standard false colour composites are prepared. The MSS false colour composite is generally created by exposing three of the four black and white bands through

different colour filters on to a colour film. In the false colour composite healthy vegetation appears bright red rather than green, water appears black, while sediment-charged water is powder blue. An urban area appear blue or grey blue.

Image display is an integral part of image processing. The computer line printer is the simplest. The computer displays the image in the form of shade print on a line printer. One band density slicing (programme Den.FOR) can be used by coding the pixels with preassessed values and intervals. Different characters are used to represent the different density ranges. The advantage of this ~~with~~ method is due to its low cost. CRT is widely used and special high resolution CRT is specifically used for image processing. The third type of device is the digital film recorder, which gives image of high quality.

For image processing CAD-P facility was used. From the available grey levels of 0-255 in the data record, this can take up a maximum of 16 grey levels. Thus, the entire range of 0-255 has to be divided into 16 levels. The program developed by K.V. Rao(1988) is used in the image generation. A histogram analysis is tentatively carried out to slice the entire range to give good quality image. The system accepts in the maximum format of 480x640 pixels. The colour coding facility uses seven primary colours and a total of 4096 colours in combinations. This is used to highlight specific features and zones.

CHAPTER III

DATA ACQUISITION AND DETAILS OF AREA

This chapter deals with the procedure of data acquisition and details of the data products and their utility to carry out remote sensing analysis.

3.1 Details of Data

To get the data for any area one needs to know the location of the area. A scene obtained by remote sensing satellite is located by certain path number and row number. Fig. (3.1) shows the Landsat pass over India and the path number, row number required for acquiring the data. Landsat data obtained for the present study consist of computer compatible tape for multi spectral mode (MSS) of 18th Sept. 1986, which gave a cloud free picture. Thematic mapper data of quadrant 'D' of the scene taken on 10th Nov. 1985. Paper prints of 1:250,000 in MSS for band 2 and band 4 and paper prints of 1:250,000 in TM for band 5, band 6, band 7 are also acquired.

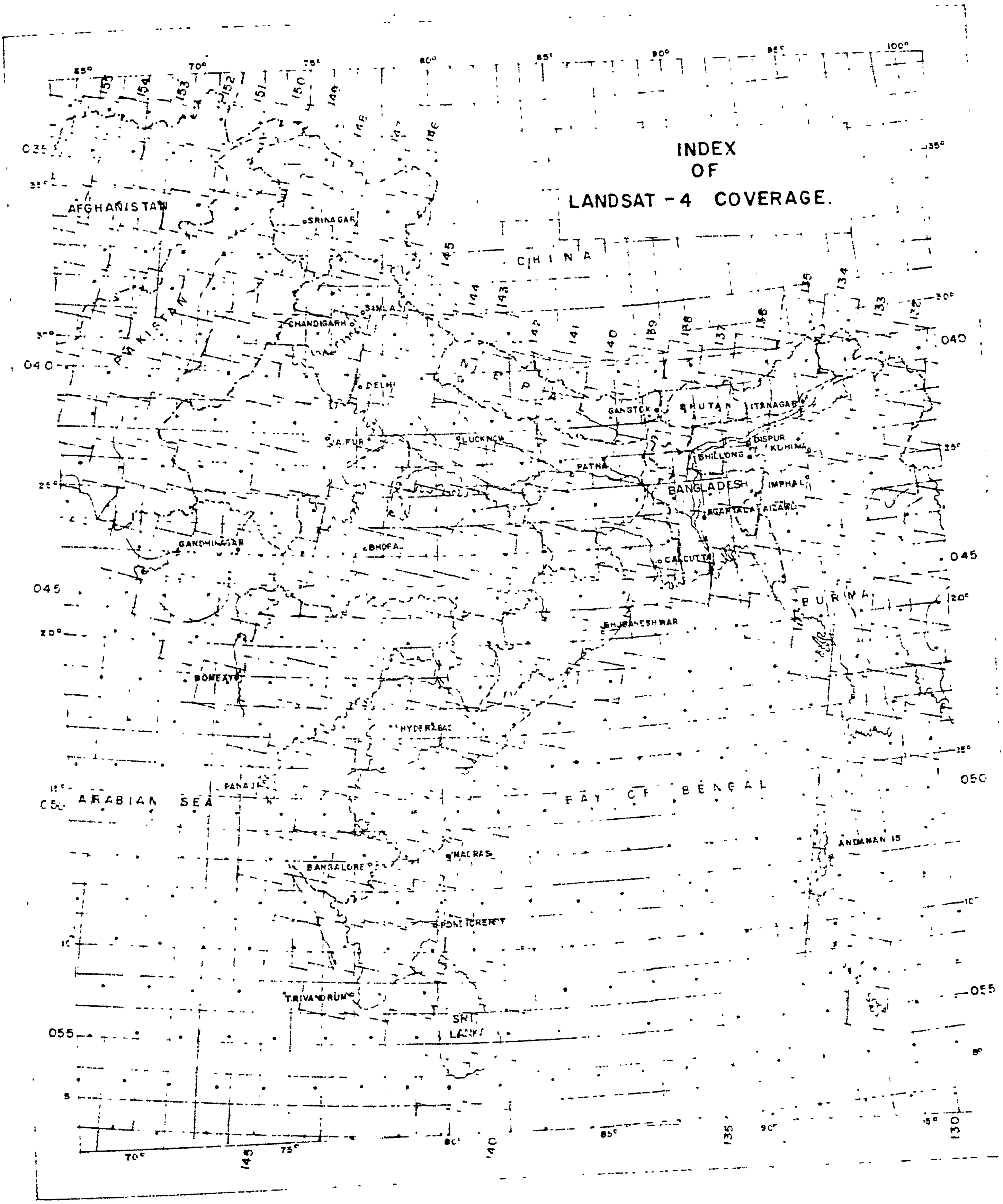

Fig. 3.1 Landsat pass over India

An area of 185 km x 185 km is covered in one Landsat scene. The information is obtained pixel by pixel and scan line by scan line. Multi spectral scanner scans the data in four bands and one pixel has the dimension of 79x79m. For thematic mapper the pixel has the dimension of 30mx30m except in band 6 (thermal infrared) where the reolution is 120 m. The scanner scans the data in seven bands.

The data collected by the scanning mirror are compared with the standard calibration source and sent to the detector where the intensity of reflectance is observed. Equivalent electrical signal ressults from the available reflectance, which is digitized and stored in computer compatible tapes (CCT), in binary form. The data of the Landsat-4 MSS is in BIL (Band Interleave) format shown in Fig.(3.2). For the comparative study the thematic mapper data is of Landsat-5 of 10th Nov. 1985 for quadrant 'D' with path No. 144 and row No.041. The quadrant identification for thematic mapper is shown in Fig.(3.3).

Thematic mapper gathers information in seven bands and hence the volume of data becomes nearly eight times the MSS volume for one scene. The format for thematic mapper is also band interleaved (BIL). The data for each quadrant is covered by 2848 scan lines and 3056 pixels per line. One data product (i.e. of a quadrant) occupies 3 tapes in 1600 bpi density.

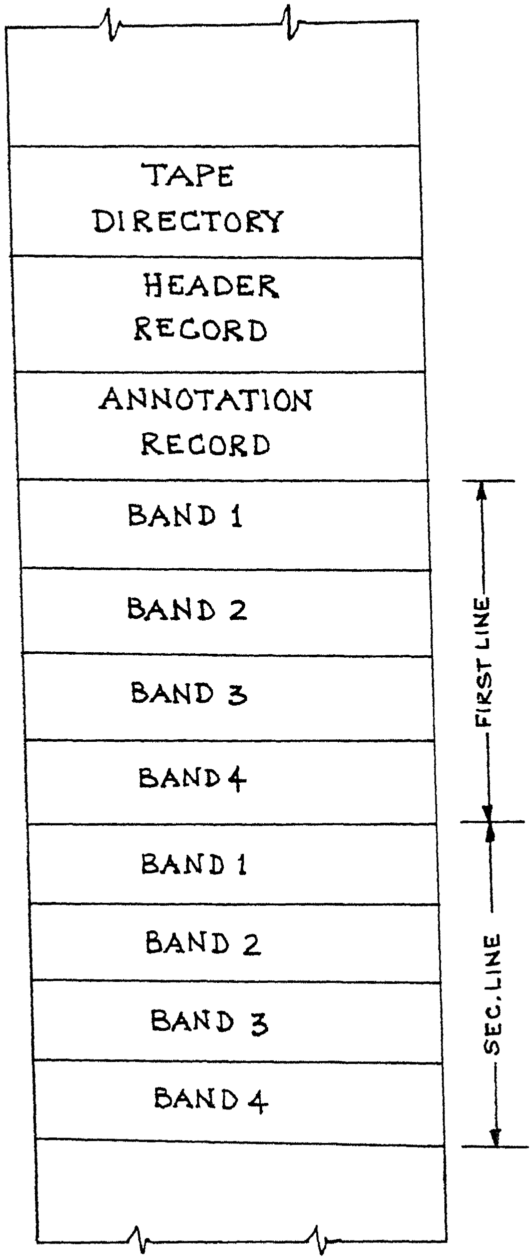

FIG.3.2 BIL FORMAT FOR MSS

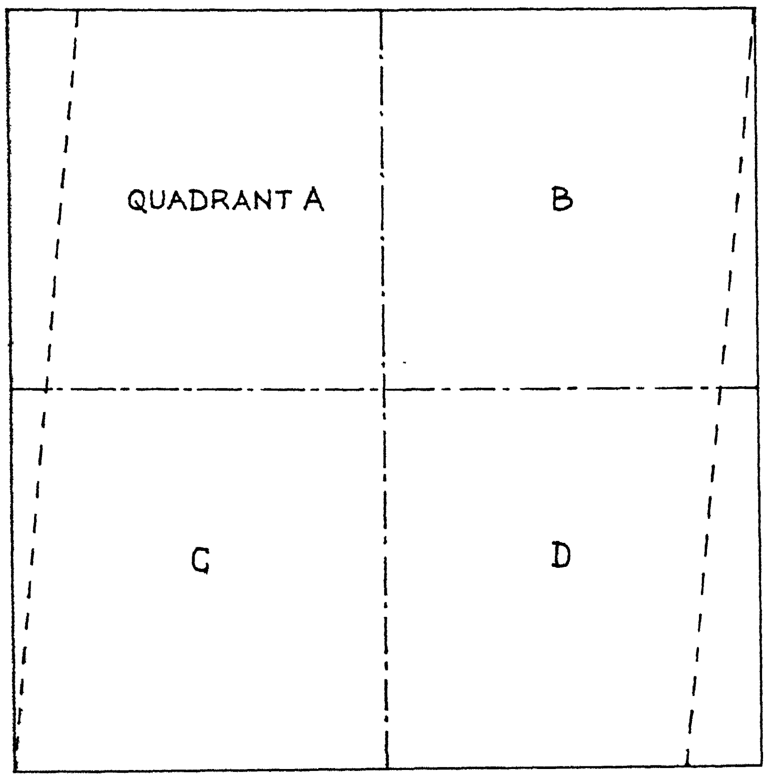

Fig. 3.3 TM Scene Quadrant Identification

Hence the volume in terms of the tapes required becomes 12 times the MSS volume for one complete scene. The 3 volumes of each quadrant cover 1000, 1000 and 848 lines respectively. The format of superstructure is shown in Fig.(3.4).

The data required for the study, i.e. CCT for MSS of Landsat-4 and TM data for Landsat-5 were acquired from NRSA B Hyderabad. Topo sheets 63B, $63\frac{B}{13}$ and $63\frac{B}{1}$ were acquired from the office of Survey of India, Lucknow. The computer compatible tape (CCT) for MSS originally acquired was in 32 bit. DEC-1090 can read the tape only in 36 bit hence the conversion is necessary. The conversion from 32 bit to 36 bit format was done by CMC Ltd. Secunderabad. Volume 3 data of TM was used in ND-560 system available in CAD-P for the generation of images.

3.2 Details of the Area

The area selected for the study is Lucknow area. The area enclosed by latitudes and longitudes is shown in Fig. (3.5).

Physiography of the Area

The regional slope of the area is towards southeast and Ramganga, Gomti and Sarda rivers flow in the same direction. Tarai plains are well developed in the region. Gomti is a

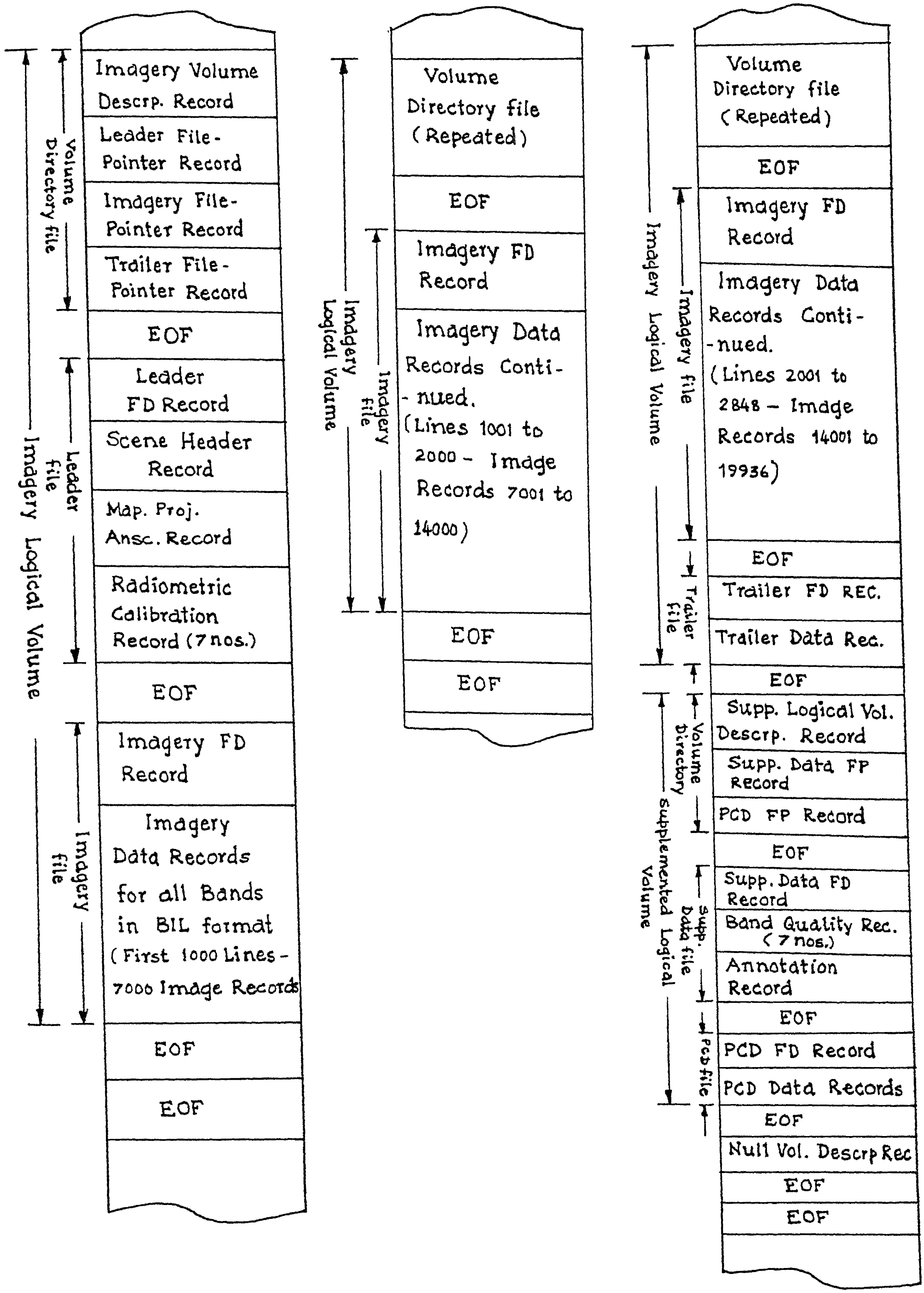

FIG.3.4 TM FORMAT SUPERSTRUCTURE

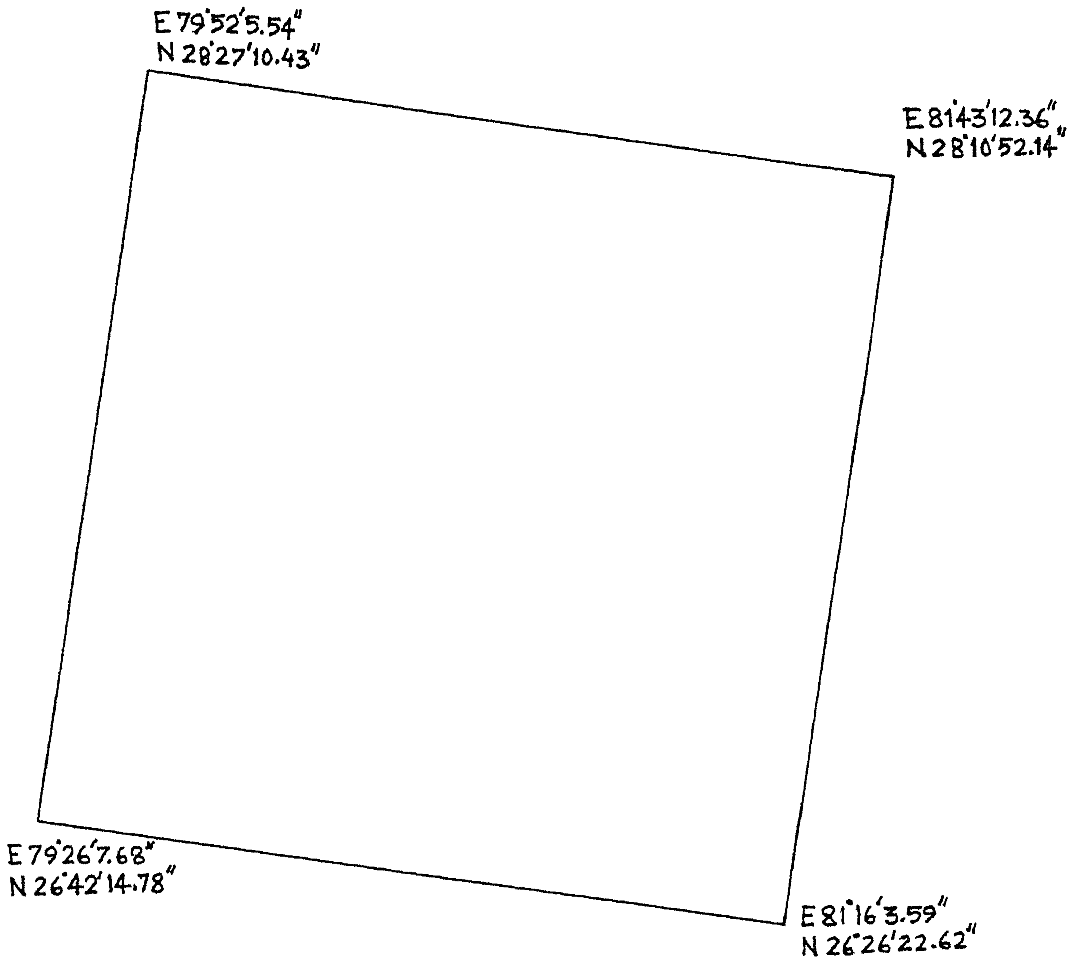

FIG.3.5 AREA OF STUDY

sluggish stream with intricate series of meanders. To the north of the area is river Ghaghra. Mean elevation of Lucknow is 111 m above mean sea level.

Weather and Climate

Typical indicators of climate are as under–

(1) Mean annual ranifall about 100 cm.

(2) (a) Mean temperature of the day – 18°C (January)

(b) Mean temperature of the day – 30°C(April)

(c) Mean temperature of the day – 30°C(July)

(d) Mean maximum temperature – 40°C

(3) Mean relative humidity 80% (at 8.30 hrs) in January.

Mean monthly values of temperature and rainfall are shown against each month.

January	Maximum temperature	– 23.3°C
	Minimum temperature	– 8.4°C
	Rainfall	– 17.5 mm
February	Maximum temperature	– 25.9°C
	Minimum temperature	– 10.8°C
	Rainfall	– 20.6 mm

	Maximum temperature	– 32.7°C
March	Minimum temperature	– 15.9°C
	Rainfall	– 8.6mm
	Maximum temperature	– 38.6°C
April	Minimum temperature	– 21.6°C
	Rainfall	– 9.1 mm
	Maximum temperature	– 40.8°C
May	Minimum temperature	– 25.7°C
	Rainfall	– 15.0 mm
	Maximum temperature	– 37.9°C
June	Minimum temperature	– 27.6°C
	Rainfall	– 88.9 mm
	Maximum temperature	– 33.6°C
July	Minimum temperature	– 26.4°C
	Rainfall	– 308.1 mm
	Maximum temperature	– 32.5°C
August	Minimum temperature	– 25.9°C
	Rainfall	– 286.5 mm

	Maximum temperature	- 33.3°C
September	Minimum temperature	- 24.7°C
	Rainfall	- 213.1 mm
	Maximum temperature	- 33.0°C
October	Minimum temperature	- 19.2°C
	Rainfall	- 35.1 mm
	Maximum temperature	- 28.8°C
November	Minimum temperature	- 12.3°C
	Rainfall	- 5.6 mm
	Maximum temperature	- 24.4°C
December	Minimum temperature	- 8.5°C
	Rainfall	6.3 mm

Geology of the Area

The detailed geology of area is not very clear. There is a thick bed of alluvium, mostly sand and silt. The depth of alluvium is of the order of 1000 m. Beneath the alluvium cover are the unconsolidated siwalik sediments and older tertiary formations. Underlying these are the more consolidated older formations such as upper Gondwana and Cretaceous. In the porous beds there are large reservoirs of fresh water. Water table in the area is upto 100-150 m below the ground level. Rock outcrop is absent in the area.

Soil Types

Detailed soil investigation has been carried out in the area by soil survey and soil work division, Department of Agriculture U.P. Soil of the area is classsified in 8 groups from the agricultural point of view. The different soil groups are-

(1) Gomti Tarai

(2) Gomti Flats

(3) Gomti Flats (Halomorphic)

(4) Gomti Uplands

(5) Gomti Lowlands

(6) Gomti Lowlands (Halomorphic)

(7) Sai Uplands

(8) Ravines

From the engineering consideration the soil cover is all alluvium.

CHAPTER IV

ANALYSIS AND INTERPRETATION

Remotely sensed data product are available in the form of computer compatible tapes (CCT), imageries in different bands and negative films which are used for visual interpretation. Analysis with the help of computer compatible tapes is a cost effective means since it can be used to generate the images using image processing. Also different classification techniques can be attempted. For the analysis of data with the help of computer, data stored in CCT (Computer Compatible Tape) is used and the study area is selected. The preliminary stages are reading the tape and calculating the constants for the area.

4.1 Preliminary Analysis

Stage I – Reading the Tape

In DEC-1090 system, it is only possible to read the tape in 36 bit format, original tape of the area processed in VAX at NRSA, Hyderabad had to be converted to 36 bit from 32 bit format by inserting dummy bytes. A programme to read the data is given (Record.FOR). The actual data of the area start from the 3rd file. The first two files are Annotation and Header records respectively. These files have to be be skipped while reading.. To read the tape with the help of the programme, the details required include the density of the magnetic tape, the record length of each file. (The record length of first two files differs from the rest of the data records).

The system available at CAD-P is ND-560 and it is possible to read the tape in 32 bit format. The tapes used are of 1600 bpi density. Although use of higher density tapes gives some problem (ie. more than 1600 bpi), it is possible to read the tapes of 800 bpi also. For reading the TM data, programme developed by K.V.Rao(1988) (programme RTM.FORT) is used.

Stage II – Calculation of Constants of the Scene –

The corner coordinates (latitudes and longitudes) for the area are computed from the available imagery for MSS. The origin of reference axes is so chosen as to place the area in the first quadrant. The origin is E79°00'00" and N26°00'00" as shown in Fig. (4.1). Corner points 1,2,3 and 4 respectively repressent line number and pixel number of (1,1), (1,3240), (2340,1) and (2340, 3240).

The programme to convert the geographical coordinates of the corner points to conical orthomorphic coordinates is given in Rampal (1982). The results after conversion are shown in table(4.1).

To get the line number and pixel number of any point from the conical orthomorphic coordinates simple transformation is used:

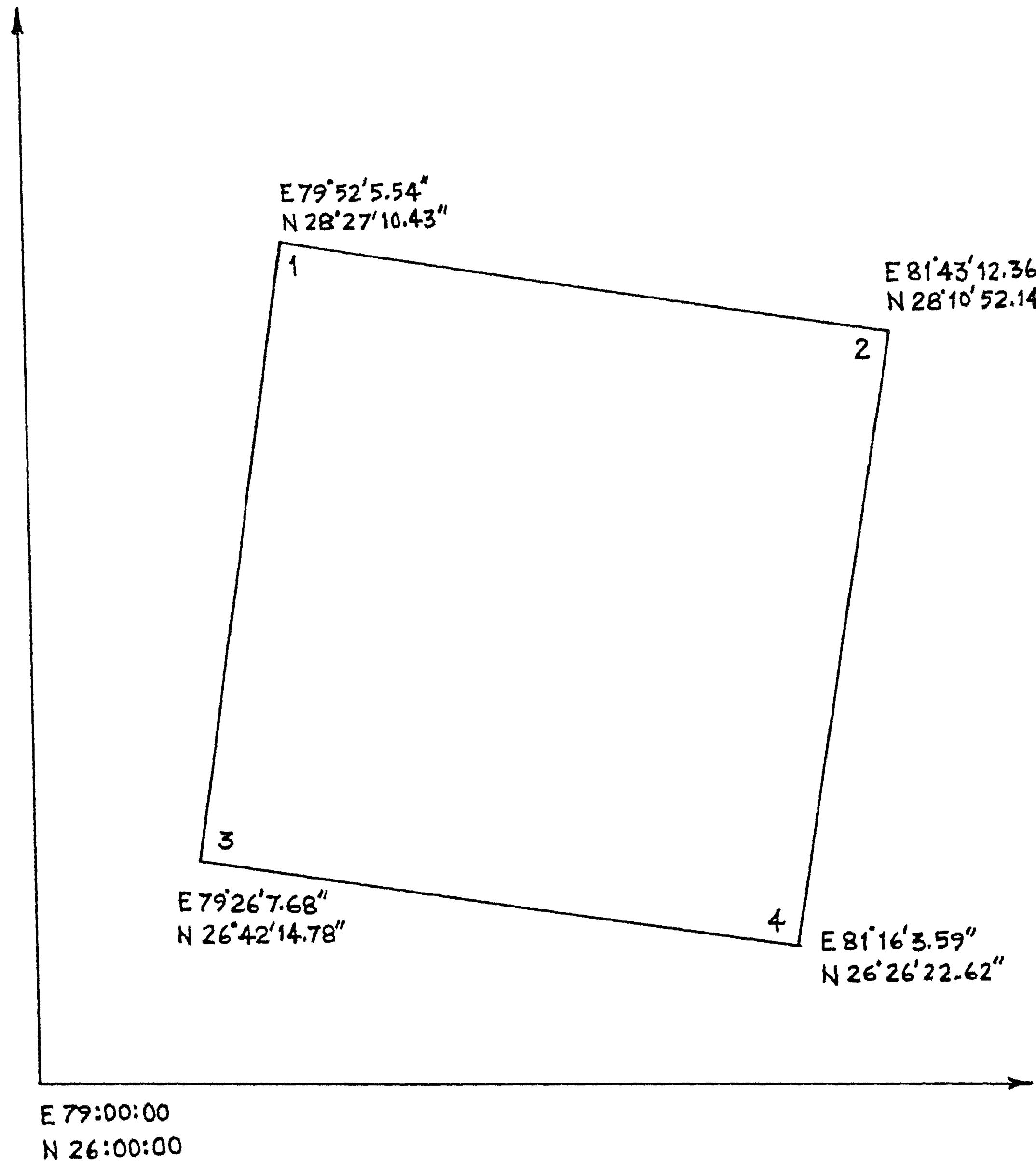

FIG. 4.1 AREA UNDER STUDY WITH REFERENCE AXES

able 4.1 : Geographical and Conical Orthomorphic Coordinates of The Scene

Corner	Geographical Coordinate		Conical Orthomorphic Coordinate	
	Longitude	Latitude	Longitude(X)	Latitude(Y)
1	79°52'5.54"	28°27'10.43"	85040.47	273383.82
2	81°43'12.36"	28°10'52.14"	267045.64	245608.78
3	79°26'7.68"	26°42'14.78"	43302.85	78443.95
4	81°16'3.59"	26°26'22.62"	225996.62	50892.18

$$X = A1x + B1y + C1$$

$$Y = A2x + B2y + C2$$

where x = line number
y = pixel number

X = conical orthomorphic coordinate of longitude

Y = conical orthomorphic coordinate of latitude

A1, B1, C1, A2, B2, C2 represent the six constants.

To solve for the six unknown constants, at least six simultaneous equations are required. This requirement dictates a minimum of three ground control points needed. The three points chosen are the 3 corners of the imagery.

The constants calculated are–

A1 = -17.84421

B1 = 56.19178

C1 = 85002.12

A2 = -83.34325

B2 = -8.575189

C2 = 273475.7

The programme(Linpix.For) uses these constants to calculate the line number and pixel number, from the given latitudes and longitudes of the points.

4.2 Visual Interpretation from the Imagery

The MSS imageries available for the study are taken by Landsat-4 on 18th September 1986. The scale of the imageries is 1:250,000. For the comparison toposheets 63B, 63 B/13 and 63 B/1 are used.

Band 1 and band 2 of MSS are the best for studying the cultural centres like urban areas, road network etc. The foressted areas have high absorbance in band 2 and are easily identified. The vegetated areas show medium tone varying from one type to another. Sediment charged water can be detected in band 2. Band 3 and band 4 are good for delineating water bodies.

River Gomti in the Lucknow area does not appear continuous in band 2 imagery due to lack of tonal contrast. Sarda canal going through the southern fringe of the Lucknow city appears in light tone. However, Haider canal is missed in the imagery. North eastern railway line has appeared in darker tone. Feature best identified on the band 2 imagery is of forest areas. Kukrail forest and other forest to the west of Lucknow city appear in very dark tone. Amongst the man made features road network is not identifiable in the imagery. Comparing it with band 4 imagery it is clear that the general information content is more in band 4.

In band 4 imagery river Gomti appears in the dark tone and hence easily identified. The urban areas appear darker in tone than the surrounding features and hence easy to delineate. The urban area has grown considerably in the last few years. The expansion of the city has been some what limited in the southern part. There is considerable growth in the north and particularly the north-western part of Lucknow area. The road network is not easy to identify. Canals are clear in band 2 and the North eastern railway line connecting Kanpur is identified in medium tone due to the tonal contrast from the surrounding agricultural land. A recent bridge built over Gomti in the western Lucknow appears in the imagery.

The MSS band 4 shows smooth texture, the variation in texture is very less. The tonal changes are apparent in the city area and the Kukrail forest area. The smooth texture and little variation in the surrounding forest areas seems to be agricultural land. The smooth texture can be due to alluvial deposits. Major geomorphic features are not seen in band 4 imagery. The soil appears well drained and medium textured in band 4. The presence of the same is apparent as point bar deposits near the banks in light tone. There is absence of shadow indicating the plain land. Scarcity of the drainage lines shows that the soil is quite permeable. The drainage pattern has intricate curves and meanders. The river has very stable course and is confined within the banks even in the greatest of discharges. In the imagery no

abandoned drainage is identified. The tributary (Behta nadi) joining river Gomti appears well in the imagery. A segment of Kukrail nadi is clear in the imagery.. Amongst other features one cut-off channel and the Sarda canal (Lucknow Branch) have appeared.

There is dramatic improvement in the thematic mapper imagery. The instantaneous field of view (IFOV) being 30mx30m. Thematic mapper imagery is available in band 5 taken on 7 Sept. 1985 by Landsat-5. Some cloud patches are seen in band 5 imagery.The effect is almost negligible in mapping surfacial features. On comparing with the MSS imagery it appears that the information content is more in TM imagery. The scale being same (i.e. 1:250,000), TM band 5 imagery shows urban area in greater detail. Block like urban pattern is very clear. The new extension of the city in the north west direction has suburban features and is comparatively less dense. Major roads and road intersections are clear and have radial features. The Northern railway line which can not be seen in the MSS band 4, appears in TM band 5. The densest part of Lucknow, near Charbagh and the railway station are clear in TM imagery. All the other features indicated by band 2 and band 4 MSS are present. Unlike, MSS band 4, some lines of secondary drainage are identified. This may be due to the greater detail coverage in TM. Also the time of satellite pass being September, an increase in discharge is expected with the saturation of soil.

The band 6 TM imagery is not very useful from the point of view to study all the surface features of the area. The resolution being 120 m,many of the features nicely shown in band 5 are not clear, although major features can be mapped. The road pattern is not clear. The band 7 imagery of 10th Nov. 1985, gives all the features mapped in band 5 but the effect of cloud is negligible. Road network and other features like newly constructed bridge are nicely shown.

The improvement in the quality and information content in TM imagery is due to the fact that the resolution is greatly improved from 79 m to 30 m. Also the TM bands which are comparable to the MSS, have been more closely ranged (table:1.2) and ~~there~~ three additional bands are included.

An analysis of band 2 in MSS of the area upstream of Kanpur, gives the features of river Ganga. The river has typical meandering anastomatic pattern (Fig.2.3). The river appears in medium light tone and the very light toned area represent the sediment deposits and silted water. The left bank is comparatively light toned than the right bank. This indicates that the area adjoining the left bank is slightly higher land. The imagery is taken in September and there is evidence of parallel drainage due to large runoff. Shifting course of river is expected and one oxbow lake is identified.

Study of Flood Plain

There is no integrated drainage pattern due to level terrain and periodic flooding. The surface drainage is constituted by a principal stream and secondary streams in high runoff season. Exceptionally light toned areas are the point bar deposits iin the river bed. The oxbow lake in the darker tone suggests that it is occupied by organic soil and is little vegetated. Natural levees of the river areas are light toned. In the band 4 MSS imagery river Ganga and its local tributaries Isan nadi and Kalyani nadi are better marked.

CHAPTER V

RESULTS AND DISCUSSIONS

The remote sensing data were obtained in the form of digital data and in the form of prints.The analysis of these data products has been carried out with the help of computer. The visual analysis of imageries have been also done. The computer aided analysis and visual analysis have been compared with the toposheets obtained from Survey of India.

5.1 Computer Aided Analysis

The main advantage with the digital data available in the form of computer compatible tapes is that the analysis can be carried out in a desired way. The digital data can be used to classify the sample pixels in a given number of categories. Also, the data can be used to generate the digital images when required.

In the present study two types of classifiers have been used. Mode seeking or clustering has been used to know the main spectrally separable classes in the area. This analysis is carried out for MSS data. The theory of clustering algorithm has been already explained in Chapter-II.

If at a certain stage of a particular cluster,

Number of samples in the cluster = n

and cluster centre is (A,B)

If a new point (C, D) is inserted in the cluster then the grade of the cluster becomes(n + 1) and the new cluster centre is also modified as

$$\left(\frac{nA+C}{n+1}, \frac{nB+D}{n+1}\right)$$

In the algorithm every time after the formation of a new cluster, the number of clusters are compared with the specified number of clusters. If the number of clusters available exceeds the specified number then the threshold is increased by a factor and iterations are performed. The procedure stops when all the data points have been classified in one or the other classes. All the possible two band combination have been tried. The results of the different combination of bands, i.e. band 1-2, band 1-3 etc. are shown in Table(5.1).

It is to be noted that vegetation and built-up areas are not spectrally separable in each wavelength due to intermixing. Also the method is not efficient for the classification but gives the number of classes available in the data. Only band 1-3 combination gives some information

Table 5.1 Results of Mode Seeking Analysis

Band Combination	Number of Samples Correctly Classified as Water	Built-up	Vegetation
1-2	50	--	41
1-3	50	49	31
1-4	50	50	8
2-3	50	48	22
2-4	50	50	19
3-4	50	50	23

where atleast three categories are clear, although good number of data samples from vegetation have been misclassified as built-up area.

If we look at the results for different band combinations it is clear that water is classified very accurately in all the band combinations. Classification of built-up area is also coming good except in band 1-2 combination. Vegetation is misclassified as built-up area. The misclassification is likely due to the recent built-up activity which is not represented in the toposheet of 1976. Another reason could be that large vegetated areas have been converted to built-up area.

5.2 Results Using Bayes Decision

This is a supervised parametric classification technique. This method is trained by a training data set which should be true representation of the category represented. To evaluate the decision, following parameters are calculated for training set -

(1) Mean values of reflectance in various bands for different categories.

(2) Variance of reflectance values in various bands for various classes.

(3) Covariance of reflectance values for all the combination of bands for all the classes.

(4) Variance-covariance matrix for each classs.

(5) Inverse of variance-covariance matrices.

Test samples are tested by computing the probability and applying the decision rule.

$$P(G_i) = e^{-1/2[(X-\mu_i)^T \Sigma_i^{-1} (x-\mu_i)]}$$

$$\ln P(G_i) = -1/2[(X-\mu_i)^T \Sigma_i^{-1} (X-\mu_i)] = -1/2\ U$$

For the conditional probability to be maximum, the value of 'U' should be minimum. A given test sample is allotted to the class for which the value of 'U' is minimum..

5.3 Training the Data -

For the training of data for Bayes classifier toposheets 63B, 63B/1 representing Lucknow area are used. Training samples from river Gomti have been used to represent water body and likewise the training samples from the urban (built-up) area and Kukrail forest area etc. have been taken. The clustering analysis indicated that only three major categories could be successfully distinguished using MSS, hence training

set (Table 5.2) comprises of four classes. Although, taking the training data in a grid pattern is better, it could not be done in such fashion due to narrow streak of Gomti and only localized forest area. The training set for TM (Table 5.3) comprises of data in six classes.

The test data set comprise of a total of 160 points in MSS, with 40 points each in one "predicted" class. For test sample of TM, 180 points have been taken.

Firstly the training data itself is classified for MSS and TM. The results have come out with 100 percent accuracy. Tables (5.4) and (5.5) respectively show the confusion matrices for the training set data. Next, the test sample data is classified and the results obtained are presented in Tables (5.6) and (5.7). It is clear from the confusion matrix that the classifier has effectively classified the sample data for MSS and TM. This gives very accurate results for 4 classes in MSS and 6 classes using TM data. For the MSS data water and urban area have been classified with 100 percent accuracy. One sample each of the Forest/Vegetation class is falling under urban area and uncultivated land due to the similarity in reflectance response and absence of sharp boundary. In TM data water is classified with 100 percent accuracy. For urban and sub-urban classes the accuracy obtained is 93.3%. Two samples from the urban area have been misclassified as sub-urban and vice-versa. This is due to the lack of sharp boundary between urban and sub-urban zones and a small localized pocket of denser sub-urban region.

Table 5.2 Training Set for MSS

Category-Water

Sl.No.	Band 1	Band 2	Band 3	Band 4
1	59	53	52	32
2	60	52	55	31
3	62	59	60	33
4	61	53	67	41
5	59	56	65	41
6	58	54	53	36
7	60	55	56	34
8	61	50	51	26
9	62	53	65	32
10	57	58	61	35

Category-Urban

Sl.No.	Band 1	Band 2	Band 3	Band 4
1	64	66	77	51
2	67	67	80	52
3	64	57	81	55
4	67	59	69	48
5	64	62	79	52
6	64	73	75	50
7	65	67	81	61
8	66	63	78	54
9	62	58	77	52
10	65	66	79	53

Category-Vegetation

Sl.No.	Band 1	Band 2	Band 3	Band 4
1	48	38	99	80
2	46	36	107	87
3	48	34	107	90
4	45	37	105	85
5	45	35	106	86
6	46	37	102	87
7	49	38	102	83
8	47	36	106	84
9	46	39	105	86
10	45	32	100	89

Category-Uncultivated

Sl.No.	Band 1	Band 2	Band 3	Band 4
1	62	48	126	104
2	56	52	123	102
3	58	51	130	105
4	59	52	129	103
5	61	55	131	106
6	57	52	125	105
7	60	53	124	107
8	61	54	126	107
9	58	50	132	103
10	59	56	130	101

MSS TEST SAMPLE DATA

S.NO.	BAND1	BAND2	BAND3	BAND4
1	58	53	66	42
2	56	53	58	38
3	57	58	59	34
4	53	52	65	46
5	56	57	60	38
6	50	55	55	36
7	57	57	60	38
8	56	54	59	36
9	56	53	66	41
10	60	57	66	42
11	60	53	66	42
12	57	52	70	46
13	64	57	55	29
14	56	56	60	32
15	60	46	66	33
16	56	56	66	35
17	56	57	66	38
18	56	53	60	33
19	56	65	70	47
20	61	62	67	36
21	64	57	62	33
22	56	57	68	42
23	59	57	51	33
24	62	55	55	33
25	61	53	65	41
26	63	57	60	34
27	64	56	59	35
28	64	57	51	29
29	54	50	58	33
30	67	57	47	23
31	64	59	53	33
32	64	57	55	29
33	53	52	50	29
34	64	60	61	29
35	64	54	55	26
36	65	54	60	36
37	62	55	61	33
38	63	54	63	32
39	62	55	60	35
40	63	54	61	33
41	60	57	81	57
42	65	60	82	60
43	65	62	80	57
44	64	57	82	52
45	60	57	83	58
46	62	58	79	60
47	69	69	80	57
48	60	72	81	57
49	59	62	78	58
50	70	65	79	52
51	68	65	84	57
52	67	68	90	58
53	60	68	88	58

54	61	70	81	56
55	63	63	77	49
56	63	64	79	59
57	61	70	81	60
58	66	64	79	55
59	71	69	72	51
60	73	70	91	61
61	69	59	79	56
62	65	65	79	53
63	65	66	78	52
64	68	68	81	53
65	65	58	82	56
66	70	69	88	59
67	69	72	90	60
68	70	67	79	58
69	60	55	75	50
70	62	56	73	50
71	63	65	77	52
72	66	65	78	50
73	65	55	80	54
74	66	60	69	49
75	61	62	78	61
76	66	68	83	65
77	63	65	73	60
78	65	69	91	63
79	62	72	90	62
80	65	67	79	53
81	45	34	104	82
82	37	46	104	78
83	45	32	103	85
84	45	44	105	81
85	45	39	100	75
86	42	42	110	87
87	41	28	107	89
88	41	53	120	84
89	47	48	107	84
90	45	32	111	90
91	43	37	100	81
92	45	36	98	82
93	48	81	87	78
94	45	29	86	81
95	47	37	112	85
96	53	49	99	81
97	41	28	107	84
98	44	45	103	84
99	48	57	109	78
100	53	49	118	85
101	43	37	104	85
102	41	28	103	84
103	47	42	117	84
104	50	40	108	92
105	43	44	113	85
106	45	50	108	81
107	47	37	104	77
108	48	41	104	78
109	47	49	99	68
110	51	48	104	78

111	47	45	98	69
112	48	43	98	86
113	50	40	102	82
114	48	38	109	89
115	51	36	109	92
116	43	45	79	89
117	49	32	98	80
118	59	56	98	82
119	58	58	99	100
120	46	30	112	95
121	63	49	126	105
122	61	47	125	103
123	57	53	125	102
124	60	61	126	107
125	55	54	122	106
126	59	52	129	104
127	62	62	133	108
128	62	59	129	101
129	50	55	121	100
130	52	53	119	99
131	60	57	131	102
132	59	51	113	104
133	62	55	112	108
134	61	54	125	108
135	56	56	123	100
136	50	48	108	95
137	51	49	109	92
138	58	52	129	104
139	59	53	132	103
140	62	54	131	105
141	63	54	130	106
142	58	68	110	104
143	68	58	98	103
144	63	65	133	102
145	58	54	131	107
146	59	55	130	101
147	60	56	131	105
148	58	52	120	102
149	51	53	100	103
150	57	67	129	103
151	62	63	122	111
152	59	69	128	109
153	57	47	127	108
154	68	42	122	109
155	67	47	124	106
156	58	54	128	100
157	62	68	98	89
158	61	51	127	105
159	62	52	132	103
160	59	60	130	102

Table 5.3 Training Set for TM

Category-Water

Sl.No./ bands	1	2	3	4	5	6	7	TVI
1	89	41	41	28	15	124	11	55
2	93	43	43	28	20	123	8	53
3	92	40	42	33	17	125	9	61
4	93	40	42	26	18	122	10	51
5	89	40	41	25	17	121	10	50
6	93	43	45	35	18	124	9	61
7	92	41	41	25	17	124	8	50
8	89	40	41	23	17	125	9	46
9	88	40	40	24	17	121	10	50
10	89	38	39	22	21	124	10	47

Category-Urban

S.No./ bands	1	2	3	4	5	6	7	TVI
1	89	38	38	34	54	127	34	66
2	88	37	38	34	52	127	33	66
3	89	37	38	38	56	127	35	70
4	90	38	38	33	53	126	35	65
5	89	38	42	36	50	127	36	65
6	89	35	36	33	45	125	34	67
7	81	35	34	38	44	124	32	74
8	84	36	36	34	46	126	33	68
9	93	40	42	35	57	126	33	64
10	86	38	38	34	52	126	34	66

Category-Sub-urban

Sl.No./ bands	1	2	3	4	5	6	7	TVI
1	86	35	35	40	59	126	40	75
2	86	36	35	44	59	124	34	78
3	86	36	34	42	60	125	30	77
4	88	36	36	40	62	127	32	74
5	88	36	38	39	59	125	31	71
6	92	41	41	38	54	123	29	68
7	91	43	46	42	61	127	37	67
8	87	37	40	41	62	124	35	71
9	86	36	36	43	58	125	34	76
10	84	37	35	42	59	126	33	76

Category-Forest

Sl.No./ bands	1	2	3	4	5	6	7	TVI
1	74	30	26	48	54	122	16	89
2	75	31	29	58	45	121	16	91
3	75	30	26	59	45	121	14	94
4	78	34	32	48	55	124	15	83
5	81	33	29	50	49	127	14	87
6	75	29	26	53	47	122	16	91
7	81	36	36	50	68	126	17	81
8	76	31	27	51	52	124	16	89
9	75	30	27	52	50	127	15	90
10	75	29	26	53	47	122	15	91

Category-Vegetation

Sl.No./ bands	1	2	3	4	5	6	7	TVI
1	89	38	38	43	63	125	35	74
2	91	41	43	45	77	125	40	72
3	90	40	40	41	66	126	41	71
4	88	38	38	62	75	126	41	86
5	93	43	49	56	93	127	36	74
6	93	44	52	58	89	127	42	74
7	90	41	42	58	77	127	40	81
8	89	41	43	50	76	125	41	75
9	86	34	35	41	66	126	41	76
10	91	41	44	51	86	127	40	75

Category-Uncultivated

Sl.No./ bands	1	2	3	4	5	6	7	TVI
1	108	54	60	56	106	126	107	68
2	110	51	57	52	103	124	108	67
3	109	53	60	55	104	122	110	67
4	97	46	52	54	102	122	112	70
5	95	46	57	56	106	126	108	70
6	99	51	52	49	100	126	109	68
7	98	49	57	58	116	125	110	71
8	102	50	58	55	99	126	111	68
9	98	51	64	67	100	120	118	72
10	97	49	60	63	114	129	115	70

54	38	42	36	53
55	35	36	34	54
56	37	39	34	56
57	37	39	33	55
58	37	37	38	49
59	35	36	36	50
60	35	35	28	38
61	37	37	38	58
62	37	37	45	74
63	38	37	40	59
64	39	39	40	60
65	37	37	38	61
66	36	34	41	59
67	41	41	39	55
68	37	37	38	60
69	36	40	40	61
70	36	36	40	59
71	37	36	41	59
72	38	36	42	60
73	38	35	38	59
74	36	36	41	43
75	41	45	42	54
76	38	39	41	57
77	38	38	39	61
78	37	38	40	61
79	41	42	41	62
80	36	36	43	59
81	40	40	40	59
82	36	37	44	59
83	37	35	41	59
84	40	41	40	60
85	36	37	43	58
86	38	43	39	60
87	37	40	40	61
88	42	44	40	68
89	40	42	42	61
90	41	44	39	58
91	35	36	37	53
92	30	26	59	44
93	30	26	52	46
94	34	32	50	46
95	29	26	49	41
96	30	29	53	50
97	35	36	53	74
98	33	31	58	64
99	32	29	53	47
100	34	32	60	59
101	36	34	54	67
102	34	34	55	51
103	31	28	53	45
104	34	35	56	53
105	30	27	51	43
106	32	27	51	47
107	30	29	58	62
108	31	27	54	45
109	33	33	48	55
110	29	25	48	43

111	32	32	49	46
112	32	32	50	37
113	30	27	58	44
114	34	34	58	66
115	36	36	50	62
116	35	35	50	55
117	34	33	42	36
118	34	32	57	53
119	33	30	53	48
120	35	37	44	65
121	37	37	50	63
122	42	45	49	83
123	40	45	45	77
124	40	43	46	73
125	43	47	50	78
126	40	42	47	81
127	30	42	49	68
128	44	50	62	78
129	41	45	54	85
130	40	45	47	58
131	41	43	48	79
132	38	38	51	65
133	41	44	50	72
134	39	41	58	70
135	39	40	55	62
136	38	40	52	60
137	40	45	60	91
138	41	45	49	77
139	34	34	45	55
140	37	38	55	85
141	37	37	56	80
142	38	41	61	86
143	45	52	66	103
144	46	55	67	91
145	42	45	61	88
146	56	65	57	120
147	36	36	49	55
148	37	38	50	45
149	44	51	58	80
150	37	37	45	70
151	42	43	25	80
152	53	60	56	100
153	54	58	30	84
154	54	61	55	102
155	45	55	58	114
156	46	59	61	114
157	51	68	66	124
158	45	55	50	94
159	46	53	59	103
160	50	60	61	106
161	46	45	56	94
162	46	55	55	84
163	46	51	48	83
164	52	61	60	99
165	47	58	56	101
166	55	66	61	94
167	49	61	64	104

168	46	61	57	101
169	49	57	58	106
170	49	60	58	110
171	54	67	67	123
171	51	66	60	106
172	48	59	55	100
173	49	55	58	93
174	50	60	60	99
175	45	52	50	93
176	49	59	59	89
177	47	56	58	112
178	48	57	59	100
179	47	58	54	92
180	43	49	45	69

Table 5.4 Confusion Matrix- MSS Training Data-

	Water	Urban	Forest/ Veg.	Uncultivated
Water	10	--	--	--
Urban	--	10	--	--
Forest/Veg..	--	--	10	--
Uncultivated	--	--	--	10

Table 5.5 Confusion Matrix-TM Training Data

	Water	Urban	Sub-urban	Forest	Veg.	Uncultivated
Water	10	--	--	--	--	--
Urban	--	10	--	--	--	--
Sub-urban	--	--	10	--	--	--
Forest	--	--	--	10	--	--
Vegetation	--	--	--	--	10	--
Uncultivated	--	--	--	--	--	10

RESULTS FOR MSS

S.NO.	CLASS NO	WU	BU	VU	FU	DECISION
1	1	5.78	39.80	284.77	2248.32	1
2	1	7.23	82.55	364.86	2583.72	1
3	1	5.86	71.10	396.37	2849.06	1
4	1	33.77	75.19	230.64	1831.45	1
5	1	5.99	74.28	357.15	2563.88	1
6	1	45.35	172.60	430.77	2604.87	1
7	1	3.42	65.26	356.83	2594.75	1
8	1	19.38	27.32	367.73	2546.80	1
9	1	11.42	55.53	288.93	2240.42	1
10	1	4.31	26.84	305.38	2336.56	1
11	1	5.22	28.14	293.32	2309.35	1
12	1	14.07	38.46	232.83	1933.37	1
13	1	12.76	53.26	491.17	3503.13	1
14	1	13.72	80.45	408.55	2889.05	1
15	1	20.36	53.87	442.90	2761.62	1
16	1	16.05	89.75	549.70	2146.06	1
17	1	10.54	58.18	317.14	2422.55	1
18	1	20.99	104.80	415.96	2826.45	1
19	1	13.50	78.77	404.41	2810.05	1
20	1	18.54	48.45	336.37	1959.50	1
21	1	10.17	31.71	359.84	2711.67	1
22	1	9.68	34.30	411.68	3071.00	1
23	1	8.97	50.18	278.53	2173.08	1
24	1	4.72	88.37	470.22	3177.12	1
25	1	50.05	88.67	597.28	3536.23	1
26	1	5.62	26.12	311.54	2415.96	1
27	1	15.09	23.54	351.91	2499.26	1
28	1	12.05	33.19	371.60	2527.35	1
29	1	17.65	63.91	522.52	3615.12	1
30	1	29.37	105.04	437.13	2777.81	1
31	1	38.72	84.54	634.69	4264.06	1
32	1	25.53	52.81	486.68	3327.80	1
33	1	12.76	53.26	491.17	3503.13	1
34	1	30.47	154.76	537.52	3198.03	1
35	1	16.29	48.01	454.67	3369.21	1
36	1	8.54	63.74	532.34	3671.15	1
37	1	20.97	32.75	532.34	3369.21	1
38	1	1.94	40.25	404.55	3006.56	1
39	1	3.73	40.56	413.38	3045.44	1
40	1	3.17	37.59	392.95	2195.23	1
41	2	31.45	11.72	204.73	1355.83	2
42	2	79.79	5.28	324.68	1367.42	2
43	2	70.81	1.76	348.55	1539.14	2
44	2	22.20	8.01	213.95	1595.35	2
45	2	33.48	12.04	196.62	1283.03	2
46	2	58.83	12.25	269.73	1329.69	2
47	2	149.98	9.87	574.41	1723.39	2
48	2	62.62	15.84	492.44	1489.39	2
49	2	36.96	21.80	293.67	1381.71	2
50	2	119.62	14.62	462.70	1960.57	2
51	2	103.91	10.20	429.77	1579.09	2
52	2	92.70	21.27	443.10	1434.25	2
53	2	42.24	16.11	347.71	1288.21	2
54	2	56.15	9.25	440.45	1531.91	2
55	2	29.28	3.21	312.15	1899.60	2

56	2	69.63	7.17	382.11	1439.46	2
57	2	72.86	14.73	490.88	1373.77	2
58	2	78.58	1.12	392.39	1688.64	2
59	2	178.06	16.97	621.77	2232.55	2
60	2	212.95	57.09	666.09	1494.89	2
61	2	111.83	11.14	375.74	1696.38	2
62	2	61.38	0.37	378.28	1756.13	2
63	2	62.76	0.42	397.09	1830.18	2
64	2	102.79	8.22	474.43	1839.67	2
65	2	55.80	3.67	271.25	1515.03	2
66	2	150.14	27.19	556.52	1524.45	2
67	2	149.80	27.32	611.06	1452.97	2
68	2	168.78	14.54	571.19	1710.04	2
69	2	15.57	13.12	217.07	1747.88	2
70	2	23.67	7.77	253.93	1850.31	2
71	2	44.30	1.80	358.28	1781.20	2
72	2	60.96	2.78	384.66	1943.66	2
73	2	49.41	4.42	247.17	1617.76	2
74	2	64.72	7.20	374.62	2135.72	2
75	2	63.02	20.40	343.40	1314.27	2
76	2	145.72	15.83	578.70	1255.82	2
77	2	98.40	27.44	478.73	1521.87	2
78	2	97.49	15.49	483.48	1183.87	2
79	2	79.44	15.56	507.24	1195.86	2
80	2	68.58	0.66	416.76	1775.79	2
81	3	387.81	237.18	17.55	250.36	3
82	3	415.07	356.72	89.02	285.78	3
83	3	420.41	258.71	13.92	233.25	3
84	3	278.72	218.04	17.67	226.99	3
85	3	302.34	202.48	26.63	365.00	3
86	3	377.67	296.53	25.80	149.76	3
87	3	576.25	352.84	47.54	224.47	3
88	3	339.93	312.38	123.67	140.24	3
89	3	232.04	198.77	55.11	176.29	3
90	3	464.19	280.69	13.79	157.81	3
91	3	368.29	265.54	26.23	276.63	3
92	3	345.92	244.79	8.25	282.03	3
93	3	228.37	210.81	43.31	444.88	3
94	3	407.99	309.23	61.47	435.35	3
95	3	356.67	221.71	11.79	162.85	3
96	3	161.12	120.80	94.77	303.79	3
97	3	565.34	323.23	84.90	258.93	3
98	3	285.99	250.90	36.04	202.35	3
99	3	157.66	163.92	135.99	268.44	3
100	3	199.90	167.37	100.30	123.78	3
101	3	167.37	100.30	7.88	207.11	3
102	3	546.93	328.59	71.90	278.03	3
103	3	317.65	224.85	28.33	137.72	3
104	3	319.35	218.13	43.12	108.75	3
105	3	347.44	269.90	31.71	146.03	3
106	3	238.53	214.11	61.30	208.10	3
107	3	310.32	184.96	23.59	313.26	3
108	3	256.55	169.08	8.56	289.64	3
109	3	178.76	147.59	48.88	526.85	3
110	3	168.35	127.57	42.88	300.33	3
111	3	204.34	151.13	38.07	509.46	3
112	3	260.70	219.60	44.72	217.50	3
113	3	254.93	163.65	8.60	252.44	3
114	3	340.71	224.23	9.37	134.95	3
115	3	357.05	214.14	28.84	120.29	3

116	3	316.46	500.25	249.77	357.81	3
117	3	336.63	183.97	27.22	339.56	3
118	3	151.85	83.20	302.88	369.36	2
119	3	334.91	243.45	739.22	126.21	4
120	3	506.23	303.24	18.68	144.06	3
121	4	386.41	257.61	543.88	7.51	4
122	4	358.41	242.41	415.54	8.77	4
123	4	287.54	232.03	442.22	2.84	4
124	4	329.14	253.47	869.47	15.25	4
125	4	319.50	261.41	529.96	10.36	4
126	4	317.69	255.85	493.23	0.24	4
127	4	340.51	286.97	957.05	21.82	4
128	4	279.72	236.39	681.81	19.00	4
129	4	262.98	255.69	362.80	27.30	4
130	4	260.82	229.80	323.59	22.63	4
131	4	277.34	251.29	597.87	6.86	4
132	4	320.07	278.70	470.60	3.83	4
133	4	379.81	269.11	744.64	4.85	4
134	4	379.20	264.32	696.35	3.96	4
135	4	252.93	215.62	464.23	12.26	4
136	4	271.49	231.45	176.25	75.62	4
137	4	238.17	195.47	157.23	89.96	4
138	4	312.63	256.94	472.49	0.75	4
139	4	299.32	265.81	495.62	2.07	4
140	4	337.51	270.37	632.69	3.42	4
141	4	361.94	272.68	683.67	4.73	4
142	4	327.07	239.05	1147.34	91.65	4
143	4	574.72	266.73	1115.70	186.69	4
144	4	281.62	262.87	919.93	39.41	4
145	4	329.50	279.22	585.49	7.08	4
146	4	272.01	244.05	504.25	4.78	4
147	4	311.56	265.12	638.48	3.45	4
148	4	305.05	218.34	450.36	9.23	4
149	4	335.44	343.43	531.03	89.18	4
150	4	247.57	243.72	896.14	41.01	4
151	4	420.93	279.14	1158.49	32.32	4
152	4	327.98	272.25	1225.07	55.10	4
153	4	387.18	284.42	423.61	15.12	4
154	4	580.96	311.95	641.54	46.18	4
155	4	474.37	277.92	639.66	27.92	4
156	4	265.16	231.60	442.10	5.71	4
157	4	253.79	120.14	887.16	349.51	2
158	4	352.28	254.56	538.33	1.45	4
159	4	323.23	271.30	541.16	5.22	4
160	4	261.84	242.93	664.32	12.74	4

RESULTS FOR TM TEST SAMPLE

S.NO.	CLASS NO.	WU	BU	SU	FU	VU	UU	DECISION
1	1	32.40	703.03	518.40	560.73	438.05	233.08	1
2	1	15.24	432.14	391.53	473.95	291.73	216.04	1
3	1	2.49	294.21	385.53	593.61	190.63	240.14	1
4	1	2.01	387.52	440.70	639.03	235.96	256.51	1
5	1	2.11	273.19	377.93	615.92	194.77	237.38	1
6	1	12.29	233.12	485.73	727.63	224.46	253.25	1
7	1	1.48	323.98	425.78	624.68	208.63	250.75	1
8	1	10.52	231.38	508.42	657.92	203.74	257.24	1
9	1	8.19	280.58	405.42	609.51	164.19	247.43	1
10	1	21.90	231.54	426.80	528.18	191.59	235.12	1
11	1	30.30	369.28	91.11	177.04	74.18	113.42	1
12	1	11.48	276.68	401.36	575.89	170.97	243.05	1
13	1	6.34	332.84	414.44	605.56	191.52	250.53	1
14	1	3.43	222.94	415.48	659.36	168.65	244.68	1
15	1	14.77	182.17	377.96	594.68	128.77	232.15	1
16	1	7.76	294.72	367.23	609.95	156.70	242.15	1
17	1	23.89	297.99	348.73	528.77	254.28	232.67	1
18	1	15.65	392.00	467.68	652.56	197.82	268.92	1
19	1	8.99	253.79	331.87	564.79	161.80	227.00	1
20	1	17.09	311.74	515.68	674.90	195.30	272.14	1
21	1	33.70	336.39	388.69	412.03	246.41	212.35	1
22	1	22.78	245.88	479.09	612.50	170.65	257.13	1
23	1	7.38	228.11	425.37	603.02	230.55	230.01	1
24	1	1.95	325.44	426.87	659.08	200.97	255.33	1
25	1	1.14	287.28	397.58	631.60	203.80	242.60	1
26	1	9.44	291.04	506.60	698.49	199.30	268.92	1
27	1	3.92	282.26	433.04	610.65	196.00	248.47	1
28	1	7.20	304.18	377.94	591.52	170.93	242.24	1
29	1	15.12	234.97	347.32	499.25	209.06	211.64	1
30	1	2.39	339.71	446.68	657.76	214.00	258.35	1
31	2	579.18	28.96	38.53	164.01	13.04	89.99	2
32	2	750.12	10.11	2.93	76.91	18.51	70.81	3
33	2	518.68	0.53	32.17	138.40	23.50	97.26	2
34	2	474.84	37.52	203.36	245.29	74.11	160.66	2
35	2	235.22	76.06	323.03	286.87	105.69	200.95	2

36	2	602.69	4.38	26.07	122.05	15.87	91.09	2
37	2	597.34	1.30	21.52	124.80	15.59	85.56	2
38	2	659.26	2.71	19.86	112.64	11.74	79.73	2
39	2	480.75	7.27	47.87	169.01	20.37	102.51	2
40	2	416.78	7.01	43.09	210.77	44.87	97.85	2
41	2	562.57	1.73	27.15	133.57	17.28	91.50	2
42	2	416.24	3.37	67.15	170.35	36.86	114.47	2
43	2	419.64	4.95	54.09	284.46	43.85	103.14	2
44	2	549.42	11.52	31.88	126.59	39.79	89.03	2
45	2	997.37	30.65	2.65	29.36	9.59	72.29	3
46	2	630.61	6.61	15.85	141.31	16.16	76.65	2
47	2	483.78	8.51	35.74	192.04	23.88	93.12	2
48	2	541.68	4.17	16.42	148.37	36.60	84.19	2
49	2	631.93	0.71	16.85	103.77	17.54	87.08	2
50	2	452.97	2.55	53.35	164.67	28.31	107.85	2
51	2	746.56	7.30	27.21	96.30	17.08	80.68	2
52	2	606.65	7.45	17.50	117.84	30.55	77.90	2
53	2	486.38	4.58	36.27	172.74	22.60	95.73	2
54	2	533.27	5.78	22.34	170.61	30.99	84.19	2
55	2	725.53	9.62	19.86	103.15	22.17	82.59	2
56	2	688.19	10.22	15.62	116.02	10.68	76.10	2
57	2	643.98	9.74	20.52	130.01	11.99	79.73	2
58	2	968.22	6.52	47.21	107.34	86.90	55.83	2
59	2	633.15	7.50	30.11	109.88	18.70	94.54	2
60	2	282.42	22.35	129.11	255.00	40.93	140.55	3
61	3	859.47	11.43	3.00	61.29	7.33	69.71	3
62	3	1751.76	107.83	8.27	11.16	57.38	41.25	3
63	3	1014.28	14.95	2.28	31.08	4.83	68.76	3
64	3	956.66	13.51	2.53	39.78	6.39	63.95	3
65	3	1023.97	20.18	3.53	38.18	7.14	62.93	3
66	3	1188.24	28.68	2.14	16.30	5.49	74.80	3
67	3	709.83	32.00	4.88	77.40	23.05	76.66	3
68	3	932.04	17.53	3.90	53.53	4.96	64.49	3
69	3	889.42	47.61	6.73	92.95	9.01	60.61	3
70	3	706.55	16.21	32.00	80.41	27.71	89.06	2
71	3	749.04	22.80	19.23	85.94	38.23	101.79	3
72	3	994.40	93.24	12.74	72.25	13.81	78.38	3
73	3	1115.14	17.95	3.55	31.16	14.89	70.50	3
74	3	539.68	18.54	22.54	100.04	50.93	121.65	3
75	3	569.74	39.74	22.89	131.17	55.04	79.41	3
76	3	841.34	12.76	2.24	52.93	13.17	72.41	3

77	3	492.89	5.93	32.39	140.05	36.52	96.02	2
78	3	961.72	24.67	24.21	43.94	51.99	122.80	3
79	3	1233.50	28.77	2.08	17.34	12.66	57.10	3
80	3	1172.77	23.36	5.53	44.46	53.99	40.32	3
81	3	889.40	17.39	2.62	48.57	10.39	65.82	3
82	3	1040.19	36.86	6.19	29.20	10.03	72.38	3
83	3	844.41	57.35	27.89	46.01	30.86	108.68	3
84	3	874.83	14.07	2.27	54.55	11.33	62.63	3
85	3	1015.31	19.39	4.01	54.03	17.48	50.91	3
86	3	757.40	23.71	8.45	129.09	17.84	62.62	3
87	3	1099.95	25.04	4.41	31.04	11.98	50.56	3
88	3	1093.43	22.39	8.29	47.25	33.90	43.16	3
89	3	894.26	20.75	2.30	54.09	13.94	59.70	3
90	3	691.96	16.03	3.73	105.20	28.06	68.36	2
91	4	1158.89	143.50	166.33	16.12	57.75	125.27	4
92	4	1711.43	190.01	285.07	5.10	86.98	216.35	4
93	4	1544.69	112.42	148.54	1.07	56.65	174.25	4
94	4	1041.33	75.73	122.36	16.04	49.45	139.92	4
95	4	1255.03	84.15	196.25	16.16	67.66	179.96	4
96	4	1407.76	130.87	145.10	8.18	53.78	149.48	4
97	4	1975.86	195.07	62.63	23.89	11.36	60.26	5
98	4	2053.27	205.84	90.67	26.05	29.07	121.45	4
99	4	1368.93	108.20	147.70	2.25	52.95	159.94	4
100	4	1821.92	201.60	137.58	20.31	37.24	138.28	4
101	4	1878.26	141.89	50.60	20.73	10.84	84.81	5
102	4	1169.56	119.78	150.86	11.10	53.84	132.26	4
103	4	1367.16	109.95	178.28	2.83	61.74	171.86	4
104	4	1186.06	131.68	155.57	15.34	53.44	125.47	4
105	4	1308.90	94.49	185.21	7.52	64.52	175.68	4
106	4	1518.98	99.26	108.37	6.48	43.28	161.50	4
107	4	2062.94	254.22	111.96	24.65	45.77	137.42	4
108	4	1504.24	125.13	181.86	2.15	62.36	181.43	4
109	4	1950.66	136.21	45.54	26.91	11.22	85.69	5
110	4	1388.85	84.70	146.71	9.30	57.11	173.51	4
111	4	855.03	57.33	103.50	35.81	93.10	137.31	4
112	4	742.27	78.28	295.96	66.89	103.13	174.70	4
113	4	1563.28	171.69	279.97	2.49	86.16	204.84	4
114	4	1875.01	300.31	92.98	20.81	22.59	101.72	4
115	4	1278.90	58.08	45.25	15.14	29.65	66.57	4
116	4	533.19	157.19	467.05	108.03	148.53	232.77	4
117	4	528.31	110.22	188.43	37.13	76.03	155.91	4

118	4	1480.69	152.26	140.25	5.80	45.44	142.54	4
119	4	2034.00	203.17	112.58	2.97	37.96	39.93	4
120	4	1257.88	84.87	7.46	5.40	29.08	57.60	4
121	5	2499.17	236.61	341.98	88.80	2.27	12.80	5
122	5	1910.42	118.68	147.29	30.07	3.35	18.12	5
123	5	1489.37	93.17	70.01	44.27	1.58	25.04	5
124	5	1411.42	67.86	45.15	24.84	1.11	33.79	5
125	5	1586.00	100.66	95.06	34.13	5.43	23.78	5
126	5	1829.45	120.79	115.71	24.35	3.59	21.89	5
127	5	1253.45	85.44	30.43	35.95	7.67	48.01	5
128	5	1674.93	257.80	183.73	70.27	29.77	37.13	5
129	5	2096.90	184.94	164.09	45.24	1.26	21.24	5
130	5	742.53	54.88	39.09	96.83	47.94	68.47	5
131	5	1771.27	98.76	103.84	21.74	1.60	25.36	5
132	5	173.22	220.28	196.05	310.20	117.48	160.33	5
133	5	1405.90	87.18	49.99	25.03	5.19	37.85	5
134	5	458.01	64.61	146.44	131.16	28.72	145.74	5
135	5	638.30	59.18	8.89	92.04	39.95	79.26	5
136	5	3139.87	369.26	403.39	130.93	27.95	18.62	5
137	5	2566.96	319.06	252.99	92.53	4.92	27.42	5
138	5	1574.39	97.89	76.85	29.66	1.51	26.65	5
139	5	1068.53	46.46	23.57	23.16	17.65	91.90	5
140	5	2540.45	267.98	164.02	65.49	19.21	43.19	5
141	5	2370.50	227.00	123.38	55.51	12.35	55.90	5
142	5	2540.81	318.81	202.85	87.09	8.55	48.68	5
143	5	3177.43	430.16	501.76	180.67	10.18	17.37	5
144	5	2136.63	225.88	259.06	6.94	17.11	94.30	4
145	5	2468.90	273.10	242.91	92.18	2.29	32.73	5
146	5	4212.09	543.83	1070.68	315.57	70.56	9.25	5
147	5	1065.78	60.64	44.08	15.89	24.78	94.93	5
148	5	659.78	94.30	151.79	62.44	80.02	125.81	4
149	5	2326.29	249.96	270.68	83.27	5.33	10.10	5
150	5	1556.55	79.76	29.46	8.41	3.68	48.39	5
151	6	1496.49	114.40	381.90	73.82	56.65	50.76	6
152	6	2479.62	341.13	228.13	80.03	15.68	14.70	6
153	6	1676.84	144.55	442.14	155.30	101.40	73.83	6
154	6	2140.36	174.02	167.22	42.55	21.75	2.76	6
155	6	3653.99	484.74	698.81	183.00	41.71	3.94	6
156	6	3586.02	517.62	679.90	215.74	27.60	2.85	6
157	6	4314.47	632.41	982.45	318.60	52.14	13.13	6
158	6	2214.75	198.43	280.06	101.40	15.94	5.22	6

159	6	2997.97	318.98	480.34	128.44	17.50	3.71	6
160	6	3046.12	346.61	562.61	155.90	31.23	0.76	6
161	6	2432.93	225.41	307.27	79.20	8.60	6.48	6
162	6	1734.93	179.99	172.37	92.56	29.51	14.32	6
163	6	1707.74	100.84	160.28	49.31	15.49	15.10	6
164	6	2588.81	320.21	449.10	137.96	46.55	2.84	6
165	6	2665.26	281.53	413.60	127.65	21.45	0.84	6
166	6	2282.97	363.24	369.91	183.39	96.53	11.80	6
167	6	2917.79	395.06	515.35	176.53	29.62	2.56	6
168	6	2651.43	355.40	395.46	208.71	25.13	2.49	6
169	6	3079.41	303.61	567.73	135.79	29.58	0.18	6
170	6	3267.37	354.34	630.10	157.45	34.72	1.11	6
171	6	4276.28	556.63	1039.60	290.54	63.13	11.51	6
172	6	2989.88	364.78	538.08	207.28	54.28	5.67	6
173	6	2587.34	253.45	402.46	123.72	27.15	2.09	6
174	6	2236.49	174.35	325.36	76.72	26.36	4.83	6
175	6	1319.29	82.09	68.09	63.11	19.92	27.49	5
176	6	2233.70	169.31	283.87	64.18	13.77	4.77	6
177	6	1667.03	111.91	83.98	25.22	30.02	0.78	6
178	6	3502.93	392.67	681.09	163.26	37.70	2.15	6
179	6	2004.24	197.33	236.37	121.90	31.76	8.66	6
180	6	1045.71	52.82	29.71	87.54	40.08	27.30	6

Table 5.6 Results for MSS Test Data

Predicted class	Number of samples ~~correctly~~ classsified as Water	Urban	Forest/ Veg.	Uncultivated	Accuracy %
Water	40	--	--	--	100%
Urban	--	40	--	--	100%
Forest/Veg.	--	01	38	01	95%
Uncultivated	--	01	--	39	97.5%

Table 5.7 Results for TM Test Data

Predicted class	Number of Samples ~~Correctly~~ Classified as Water	Urban	Sub-urban	Forest	Veg.	Uncultivated	Accuracy %
Water	30	--	--	--	--	--	100%
Urban	--	28	02	--	--	--	93.3%
Sub-urban	--	02	28	--	--	--	93.3%
Forest	--	--	--	27	03	--	90%
Vegetation	--	--	02	--	28	--	93.3%
Uncultivated	--	--	--	--	01	29	96.6%

As can be expected 3 samples from the predicted forest class are classified as vegetation due to lack of dense cover. Two samples from vegetation classified into sub-urban class suggest the increase in vegetated areas.

For a classifier increase in the number of classes is associated with decrease in the classification accuracy. But the analysis using TM data indicates that even after increasing the classes from four to six, the classification accuracy is maintained over 90 percent for all the classes. The Survey of India toposheet used for taking training set data has 1:50,000 scale. This has resulted in taking the training data accurately and a correct cross check with the test sample data.

Table (5.3) for the training data set for TM shows the values of tranformed vegetation index against each class. It can be seen that the value of this vegetation index increases with increase in vegetative component. For the present training set a value of more than 70 has good vegetation content. For forest, the values are still higher as shown in the Table. This vegetation index can be used to reclassify the vegetation types. In an area which is intensely cropped and has various types , it is possible to classify it in different crop zones.

Although six categories have been taken in TM, the features such as roads, canal etc. fall in one or other class. Such features can be called as micro clases. Roads, if metalled would come under the urban and sub-urban classes. Typical village roads and earthen roads would be classified under the bare soil due to close resemblence in reflectance. The use of classiifier is limited in such situations and use of imageries should be preferred.

5.4 Results of Image Processing -

The simplest way to get the image display is through the computer line printer. One band density slicing is done to slice the entire range of reflectance values in given number of classes in the scene. Fig.(5.1) shows the line printer map for band-4 data. It can be seen that except the river pattern, it does not convey substantial information. It essentially lacks the quality to create an impression on the brain. But the method is very simple and easy to apply since no special system is needed. The display is very quick.

5.5 Comparison of Map and the Imagery

To prepare a map is a hard and strenuous job. It requires labour and heavy expenses. It is difficult to take up the exercise of updating the map at very short intervals. An imagery on the other hand is a data product generated from the digitized data. Although the imagery does not give the information in complete details, it can be used to study the temporal changes.

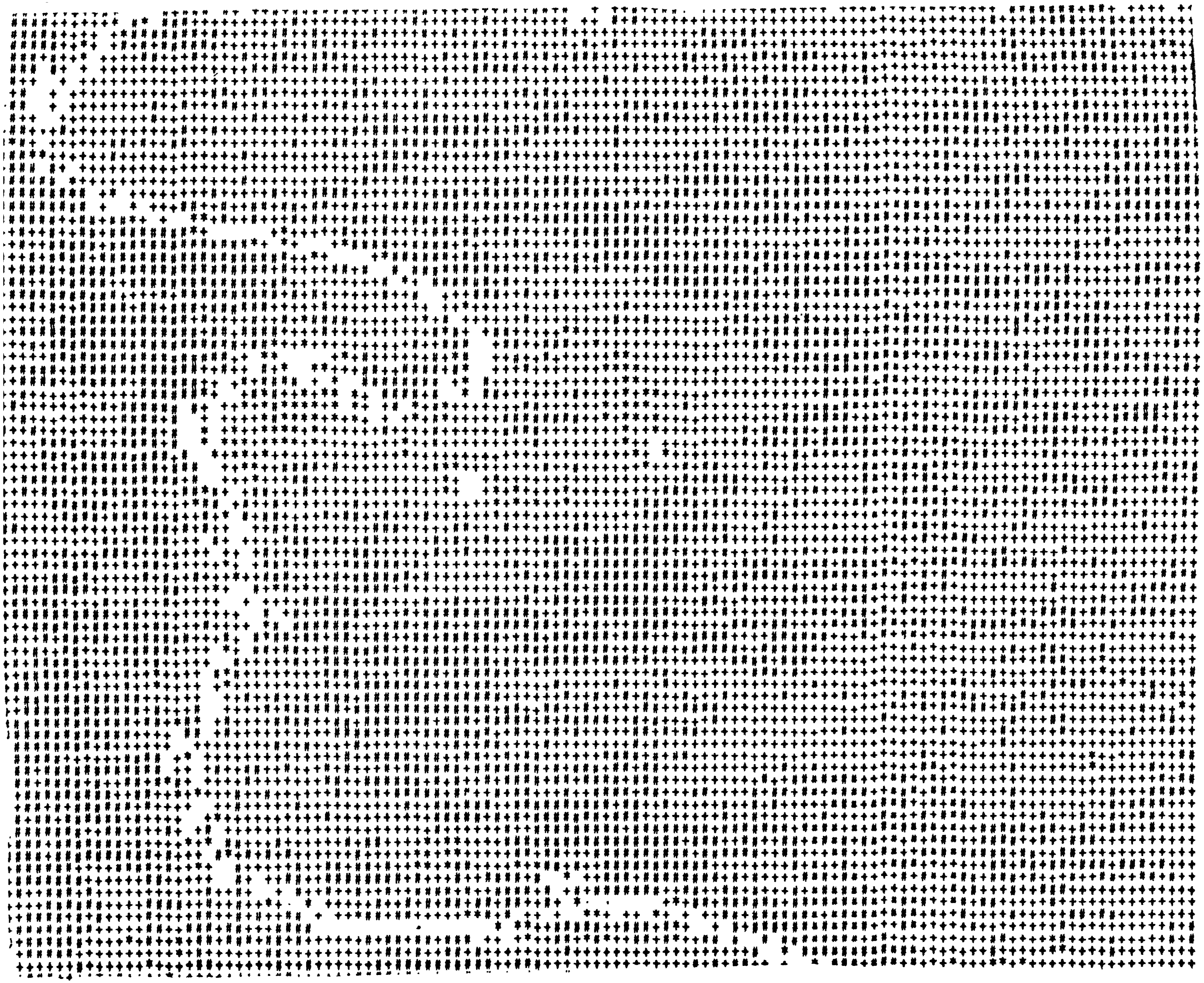

Fig. 5.1 Band-4 Density Slicing

Figures (5.2) and (5.3) show the details covered in the map and the imagery respectively for the Lucknow area. The two figures resemble quite closely in respect of the main features. Particularly the river pattern of Gomti compares very well. This suggests that a time lag of ten years has not changed the river course.

Figures (5.4) and (5.5) show the comparison of the map details and the details covered by imagery for the pattern and flood plain of Ganga.. The general pattern agrees in the two figures, but within the natural limits the river has a tendency to shift as shown by the imagery. There is continuous change due to silting and deposition of sediments, typical of anastomatic pattern.

5.6 Comparison of MSS and TM Digital Images -

Digital images are very useful where the facilities exist to carry out image processing techniques. Apart from the simple one band digital images, filtered and zoomed images are used to enhance and enlarge specific features.

Plate 1 and Plate 2 show the digital images in band 2 of MSS and TM. Forest and vegetative features are highlighted. The area covered by the TM image is about one seventh of the coverage in MSS. It can be seen that for studying the lineaments MSS image is more suitable.

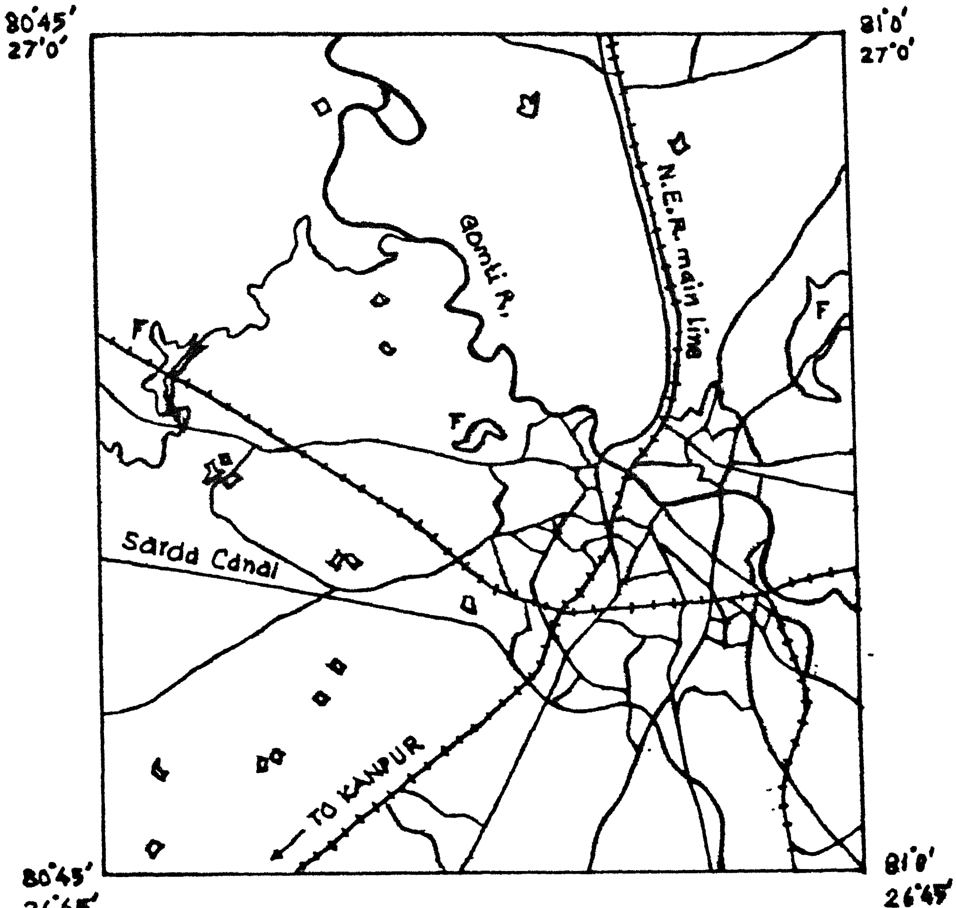

Fig. 5.2 Details from Map

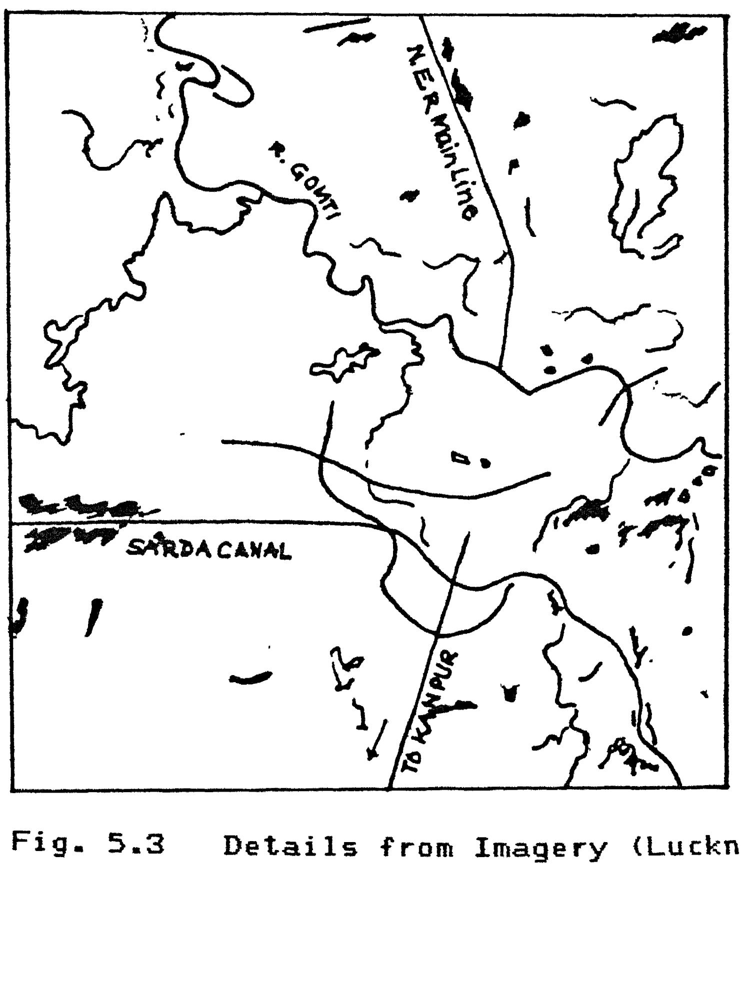

Fig. 5.3 Details from Imagery (Lucknow Area)

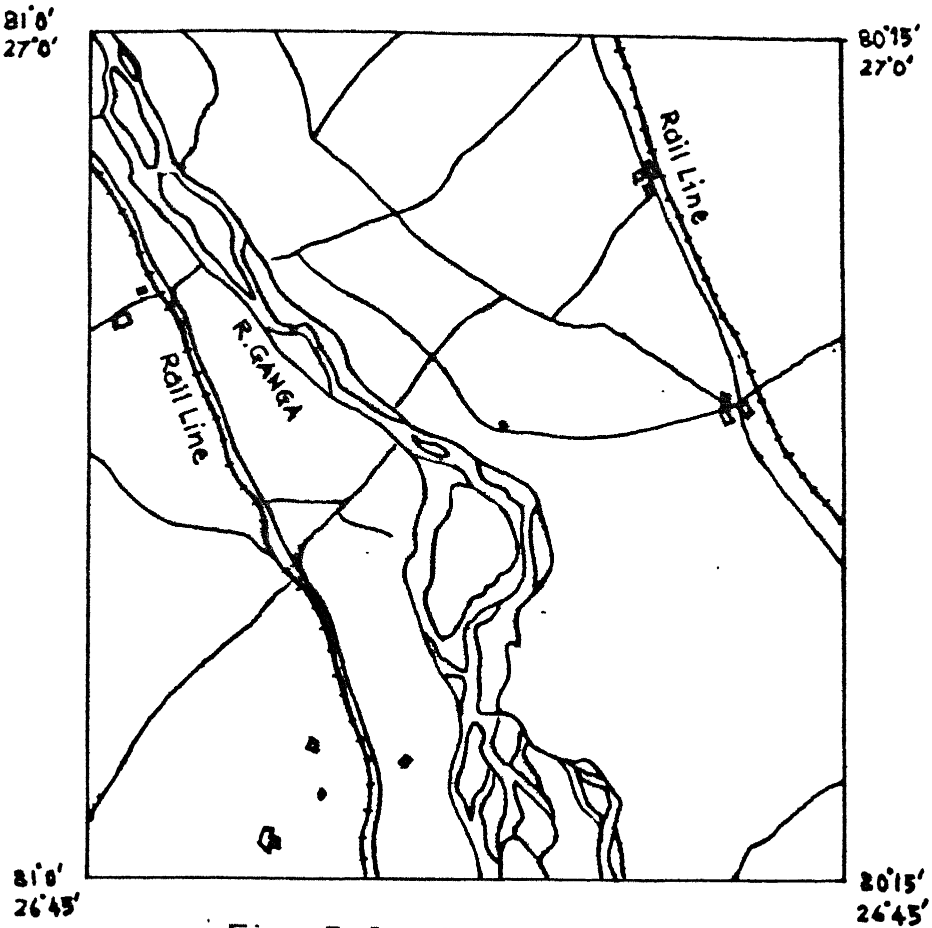

Fig. 5.4 Details from Map

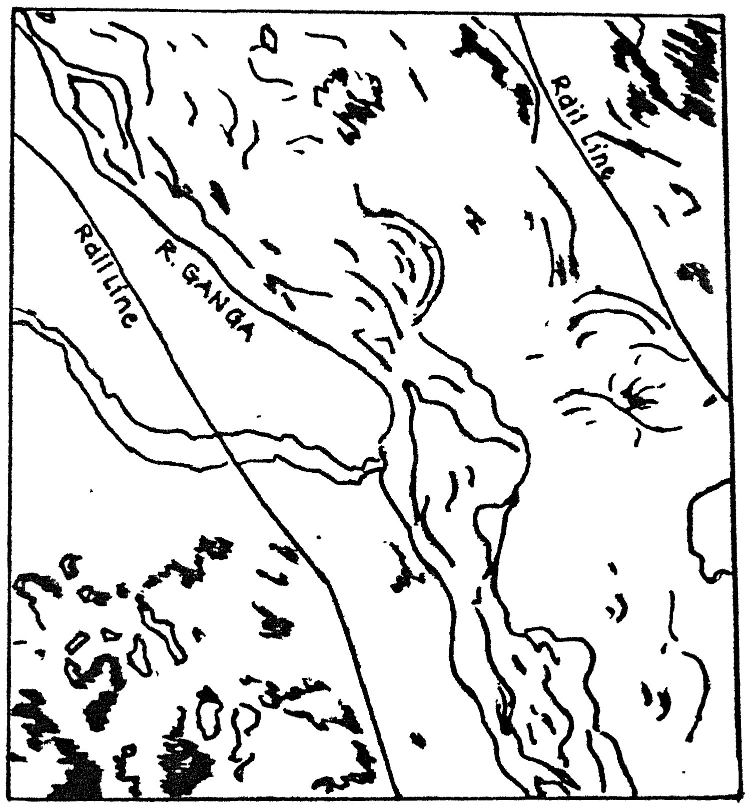

Fig. 5.5 Details of Imagery (Flood Plain of Ganga)

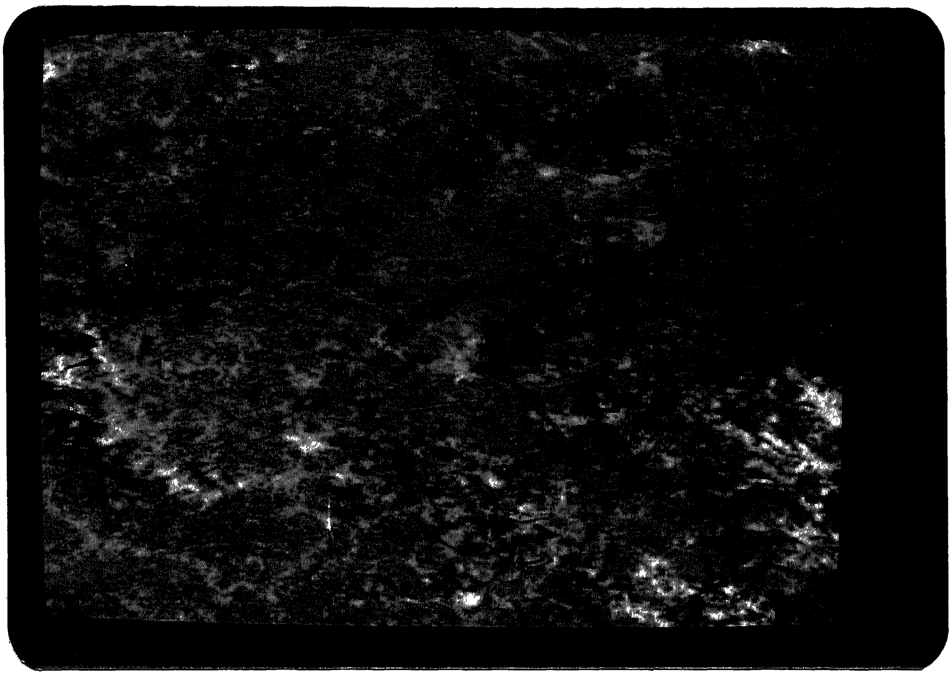

Plate 1

Plate 2

Plate 3 and Plate 4 show the false colour images in band 2. False colour images are useful for differentiation when difference of grey level is difficult to perceive.

Plate 5 and Plate 6 show the digital images in band 4. In MSS image there is little variation in level in surrounding area around urban land. There is greater coverage in MSS and effect curvature of the screen is also pronounced. The TM image shows two bridges over the river Gomti.

Plate 7 is the false colour image in band 4. Urban area near Charbagh is misclassified. Brown colour shows the sub-urban fringe. It also covers the land recently opened up for built-up activity.

Plate 3

Plate 4

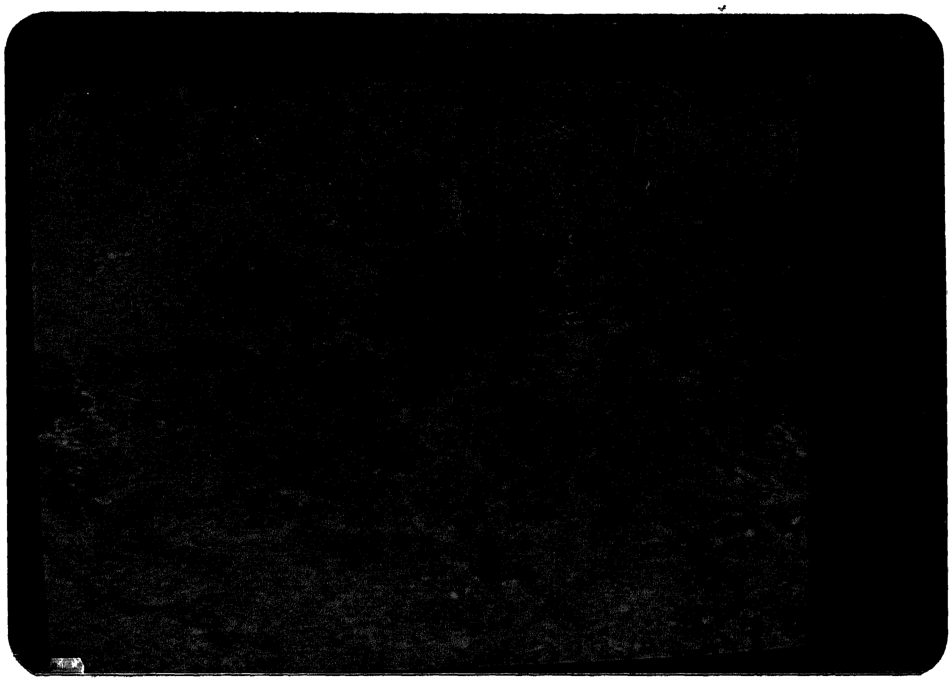

Plate 5

Plate 6

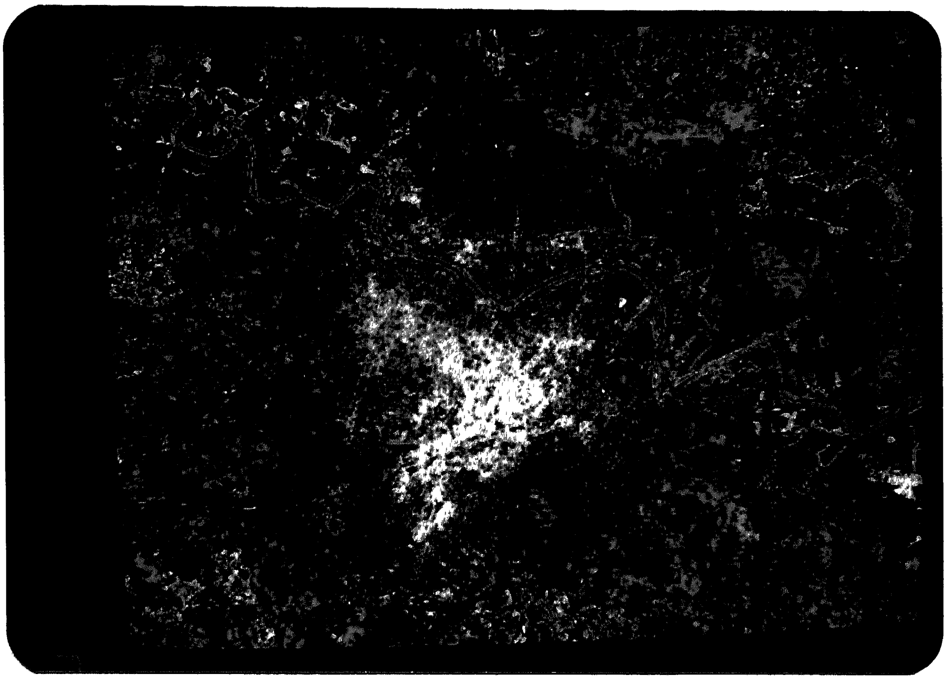

Plate 7

CHAPTER VI

CONCLUSIONS AND FUTURE RECOMMENDATIONS

6.1 Conclusions

The present study establishes the utility of various data products for the analysis of the remotely sensed data. The two modes of data collection i.e. multispectral scanner and thematic mapper have their limitations.

By supervised classification for the samples we arrive at the following conclusions:

(i) For general analysis MSS data can be used but it can not classify the micro classes like roads, railway lines etc. due to coarse resolution of 79m.

(ii) TM data is very useful when the classes in the scene are many. It is possible to classify the microclasses.

(iii) Handling of TM data is little difficult because of the volume of data. Also it costs about eight times the cost of the MSS data. Hence for general purposes MSS data shall find its use.

The use of imagery alone is not very useful unless available with the digital data. This is due to the fact that the digital data can be controlled in a desired way but imagery can not. It is very easy to produce the digital image for selected area and perform other techniques of image processsing.

6.2 Future Recommendations

Bayes classifier is very efficient classifier. In an area where there is wealth of variety, it is a very useful tool when TM data is used. To get the best results from the classifier all the seven bands can be used. Different 4 band combination can also be tried to get the best combination of bands. This would save the computational time.

For complete classifiation of the image data vegetation can be re-classified into sub-classes using vegetation indices. For the detailed study of the urban area, image data can be zoomed and then contrast stretched. This would differentiate amongst residential, commercial and industrial zones.

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L
C       PROGRAM DENSTY.FOR
C       ------------------------------------------------------------
C       THIS IS AN INTERACTIVE PROGRAM FOR MAPPING THE
C       SURFACE FEATUURES BASED ON THE DENSITY SLICING METHOD
C       PROGRAM IS FOR EFFECTIVE FOR 10 CLASSES
C       THERE IS NO LIMIT ON THE LENGTH OF THE INPUT BUT
C       THE NUMBER OF PIXELS PER LINE SHOULD NOT EXCEED  960
C       ---------------------------------------------------------------------
C
        INTEGER IPIX(960),INTMAT(960),GREY(10)
        INTEGER CONTOR(10),INTVL(10),UPLIM(10),LOWLIM(10)
        OPEN(UNIT=25,DEVICE='DSK',FILE='INPUT')
        OPEN(UNIT=6,DEVICE='DSK',FILE='MAP1')
        OPEN(UNIT=7,DEVICE='DSK',FILE ='MAP2')
        OPEN(UNIT=8,DEVICE='DSK',FILE='MAP3')
        OPEN(UNIT=9,DEVICE='DSK',FILE='MAP4')
        OPEN(UNIT=10,DEVICE='DSK',FILE='MAP5')
        OPEN(UNIT=11,DEVICE='DSK',FILE='MAP6')
        OPEN(UNIT=12,DEVICE='DSK',FILE='MAP7')
        OPEN(UNIT=13,DEVICE='DSK',FILE='MAP8')
C
C       INTERACTION BEGINS
C
        TYPE 10
10      FORMAT('    ALL TERMINAL INPUT IS FORMAT FREE',//,
        18X,'TYPE IN THE NUMBER OF CLASSES FOR SLICING')
        ACCEPT *,NCLASS
        TYPE 20
20      FORMAT(8X,'TYPE IN CHARACTERS FOR REPRESENTATION
        1 OF THE CLASSES')
        ACCEPT 25,(GREY(I),I=1,NCLASS)
25      FORMAT(10A1)
C
C       TO GET THE CONTOUR LEVEL AND INTERVAL OF EACH CLASS
C       FROM TERMINAL
C
        DO 30 I=1,NCLASS
        TYPE 40,I
40      FORMAT(8X,'TYPE IN THE CONTOUR LEVEL AND INTERVAL',I2)
        ACCEPT *,CONTOR(I),INTVL(I)
        UPLIM(I)=CONTOR(I)+INTVL(I)
        LOWLIM(I)=CONTOR(I)-INTVL(I)
30      CONTINUE
        TYPE 50
50      FORMAT(8X,'TYPE IN THE LENGTH AND BREADTH OF INPUT')
        ACCEPT *,NLINE,NPIX
        TYPE 55
55      FORMAT(8X,'TYPE IN THE NUMBER OF OUPUT FILES')
        ACCEPT *,NOUTFL
C
C
C       INTERACTION ENDS.
C       TO INITIALISE THE INTERMEDIATE MATRIX INTMAT
C
        DO 65 I=1,NPIX
```

```
65      INTMAT(I)=' '
C
C       TO READ AND CLASSIFY THE INPUT DATA
C
        ILOOP=0
60      CONTINUE
        READ(25,*)(IPIX(I),I-1,NPIX)
        ILOOP=ILOOP + 1
        DO 70 I=1,NPIX
        DO 70 J=1,NCLASS
        IF((IPIX(I).LE.UPLIM(J)).AND.(IPIX(I).GE.LOWLIM(J))
        1INTMAT(I)=GREY(J)
70      CONTINUE
C
C       To transfer the results from INTMAT to output files
c       for getting the line printer map.
c
        NUNIT=6
        M=1
        N=M+119
        DO 80 I=1,NOUTFL
        WRITE(NUNIT,90)(INTMAT(J),J=M,N)
90      FORMAT(120A1)
        NUNIT=NUNIT+1
        M=N+1
        N=M+119
80      CONTINUE
        IF (ILOOP.LT.NLINE) GOTO 60
        STOP
        END
```

```
C       READ.FOR
C       PROGRAMME TO REAAD CCT ON ND-560 COMPUTER
C       PROGRAMMED BY K.V RAO
        INTEGER*1 IBUF(4000)
        OPEN(UNIT=25,FILE='INPUT:DAT')
        DO FOR K=1,2
        ISTAT=MAGTP(10B,IDUM,40B,IDUM,IDUM)
        END DO
        DO FOR I=1,1680
        ISTAT=MAGTP(16B,IDUM,40B,IDUM,IDUM)
        END DO
        DO 3 M=1,290
        ISTAT=MAGTP(26B,IBUF,40B,4000,IDUM)
        WRITE(25,4)(IBUF(J),J=1300,1589)
4       FORMAT(50I4)
        DO FOR N=1,6
        ISTAT=MAGTP(16B,IDUM,40B,IDUM,IDUM)
        END DO
3       CONTINUE
        CLOSE(25)
        STOP
        END
```

```
C       Prodrom RECORD.FOR
C
C

C       PROGRAM TO READ AN IMAGE LINE OF THE CCT
C       THIS PROGRAM READS ONE RECORD OF CCT. THIS IS VALID AFTER
C       INSERTION OF 5 , 10DUMMY BLANKS OR AFTER CONVERSION OF
C       CCT FORMAT INTO DIC-10 COMPATIBLE.

C       ************************************************************

        INTEGER OCT(1125),BT1,BT2,BT3,BT4,BT5
        OPEN(UNIT=53,DEVICE='DSK')
        OPEN(UNIT=50,DEVICE='DSK')
        OPEN(UNIT=45,DEVICE='DSK')
        OPEN(UNIT=20,DEVICE-'MTA1',MODE-'DUMP',RECORD SIZE-1125,DENSITY
        1='1600')
        NO=-3
        READ(20)OCT
        DO 1200 I=1,1125
        NO=NO+4
        BT1=OCT(I)/2**28
        BT2=(OCT(I)-BT1*2**28)/2**20
        BT3=(OCT(I)-BT1*2**28-BT2*2**20)/2**12
        BT4=(OCT(I)-BT1*2**28-BT2*2**20-BT3*2**12)/2**4
        WRITE(53,11)NO,BT1,BT2,BT3,BT4
11      FORMAT(5I5)
1200    CONTINUE
        CALL CONE
        CLOSE(UNIT=20,DEVICE='MTA1',MODE='DUMP',RECORD SIZE=1125,DEN
        1SITY='1600')
        STOP
        END
        SUBROUTINE CONE
        DIMENSION NAT(25)
        COMMON NAT
        REWIND 53
        DO 101 I=1,180
        READ(53,10)(NAT(K),K=1,5)
        READ(53,10)(NAT(K),K=6,10)
        READ(53,10)(NAT(K),K=11,15)
        READ(53,10)(NAT(K),K=16,20)
        READ(53,10)(NAT(K),K=21,25)
        WRITE(50,21)NAT
21      FORMAT(25I5)
101     CONTINUE
10      FORMAT(5I5)
        RETURN
        END
```

```
C       ------------------------------------------------------------
C       PROGRAM:  PIXEL.FOR
C       ------------------------------------------------------------
C       This prodram is to read a record of the CCT to get the
C       gray level of certain pixel whis has to be fed into
C       program while under execution.
C       This program also provides the reflectance values
C       of five  pixels on either side of the wanted one.
C       ------------------------------------------------------------
        INTEGER OCT(1125),BT1,BT2,BT3,BT4,BYTE(4000),ABC(11)
        INTEGER RECORD,BAND
        OPEN(UNIT=53,DEVICE='DSK')
        OPEN(UNIT=50,DEVICE='DSK',FILE='PIXEL')
        OPEN(UNIT=20,DEVICE='MTA1',MODE='DUMP',RECORD SIZE=1125,
        1DENSITY='1600')
        TYPE 30
30      FORMAT('    TYPE IN THE PIXEL NUMBER PLEASE')
        ACCEPT *,IPIX
        READ(20)OCT
        J=1
        DO 1200 I=1,1125
        BT1=OCT(I)/2**28
        BYTE(J)=BT1 ; J=J+1
        BT2=(OCT(I)-BT1*2**28)/2**20
        BYTE(J)-BT2; J-J+1
        BT3=(OCT(I)-BT1*2**28-BT2*2**20)/2**12
        BYTE(J)=BT3; J=J+1
        BT4=(OCT(I)-BT1*2**28-BT2*2**20-BT3*2**12)/2**4
        BYTE(J)=BT4; J=J+1
        K-I*4; IPIXU-IPIX+400
        IF (K.GE.IPIXU) GOTO 31
1200    CONTINUE
        CLOSE(UNIT=20,DEVICE-'MTA1',MODE='DUMP',RECORD SIZE=1125,
        1DENSITY='1600')
31      RECORD-BYTE(7)+BYTE(8)*256
        IBUFF=RECORD/4
        BAND=RECORD-IBUFF*4
        LINE=BYTE(11)+BYTE(12)*256
        WRITE(50,111) LINE,IPIX
111     FORMAT(15X,'LINE NUBER= ',I4,'  PIXEL NUMBER =',I5)
        WRITE(50,112)BAND,RECORD
112     FORMAT(/,15X,'BAND  =',I4,'    RECORD NUMBER = ',I5)
        IZERO=1
C       TO COUNT THE LENGTH OF THE INITIAL ZERO FILL
C       ------------------------------------------
        DO 125 I=17,400
125     IF (BYTE(I).EQ.0) IZERO=IZERO+1
        TYPE *,IZERO,IZERO
        IPIXEL=IPIX+IZERO
        IPIXU=IPIXEL + 5
        IPIXL=IPIXEL - 5
        J=1
        DO 113 I=IPIXL,IPIXU
        ABC(J)=BYTE(I)
        J=J+1
113     CONTINUE
```

```
      WRITE(50,114)ABC
114   FORMAT(//,15X,'REFLECTANCE COUNTS ARE'//,15X,11(I5))
      WRITE(50,115)
115   FORMAT(/,44X,'^',/,44X,'!',/,36X,
     1'WANTED  PIXEL',//,15X,55(1H-))
      TYPE *,LINE,IPIX,BYTE(IPIXEL)
      STOP
      END
```

```
C     ----------------------------------------------------------
C     THIS PROGRAM READS A RECORD OF THE CCT BUT THE
C     OUTPUT WILL BE ONLY A PART OF IT.
C     ----------------------------------------------------------
      INTEGER OCT(1125),BT1,BT2,BT3,BT4,BYTE(4000),LOWER,UPER
      OPEN(UNIT=53,DEVICE='DSK')
      OPEN(UNIT=50,DEVICE='DSK',FILE='PART')
      OPEN(UNIT=20,DEVICE='MTA1',MODE='DUMP',RECORD SIZE-1125,
     1DENSITY='1600')
      READ(20)OCT
      LOWER=1701
      UPER=1800
      J=1
      DO 1200 I=1,1125
      BT1=OCT(I)/2**28
      BYTE(J)=BT1; J=J+1
      BT2=(OCT(I)-BT1*2**28)/2**20
      BYTE(J)=BT2;J-J+1
      BT3=(OCT(I)-BT1*2**28-BT2*2**20)/2**12
      BYTE(J)=BT3; J-J+1
      BT4=(OCT(I)-BT1*2**28-BT2*2**20-BT3*2**12)/2**4
      BYTE(J)=BT4; J=J+1
 1200 CONTINUE
      CLOSE(UNIT=20,DEVICE='MTA1',MODE='DUMP',RECORD SIZE=1125,
     1DENSITY='1600')
      IZERO=0
C     TO WRITE THE DATA
      DO 3000 I=17,400
 3000 IF (BYTE(I).EQ.0) IZERO=IZERO + 1
      LOWER=LOWER + IZERO
      UPER=UPER + IZERO
      WRITE(50,*)(BYTE(K),K=LOWER,UPER,5)
      STOP
      END
```

```
      DIMENSION X(200),Y(200),DIS(50),CLSTXC(50),CLSTYC(50)
      INTEGER TAG(200),NCLST(50)
      DATA NCLUST,NPTS,THRESH/4,200,1.25/
      OPEN(UNIT-31,FILE-'N.DAT')
      WRITE(22,11)NCLUST,NPTS,THRESH
20    CONTINUE
      DO 54 I=1,10
54    NCLST(I)=0
      REWIND 31
      II   =1
      NCL  =1
C     READ THE FIRST SAMPLE VALUE
C
      READ(31,*)X(II),Y(II)
      CLSTXC(NCL) =X(II)
      CLSTYC(NCL) =Y(II)
      TAG(II)     =NCL
      NCLST(NCL)  =NCLST(NCL)+1
C
C     READ THE NEXT SAMPLE VALUE
10    CONTINUE
      II=II+1
      READ(31,*)X(II),Y(II)
C     CALCULATE THE SQARE
      DO 100 I=1,NCL
      DIS(I)=DIST(CLSTXC(I),CLSTYC(I),X(II),Y(II))
100   CONTINUE
C
C     FIND THE NEAREST CLUSTER CENTRE
C
      DISMIN =DIS(1)
      DO 200 I=1,NCL
      IF(DIS(I).GT.DISMIN) GO TO 200
      DISMIN=DIS(I)
      NCUR =I
200   CONTINUE
C
C     TEST WHETHER SAMPLE IS WITHIN THRESHOLD OF THE
C     NEAREST CLUSTER
C
      IF (DISMIN.LT.THRESH)GO TO 310
      CLSTXC(NCL) =X(II)
      CLSTYC(NCL) =Y(II)
      NCL =NCL+1
      TAG(II) =NCL
      NCLST(NCL)=NCLST(NCL)+1
      IF(NCL.GT.NCLUST) GO TO 330
      GO TO 500
310   TAG(II)= NCUR
      ANCLS =NCLST(NCUR)
C
C     UPDATE THE VALUE OF THE CLUSTER CENTRE
```

```
      CLSTXC(NCUR) =(ANCLS*CLSTXC(NCUR) +X(II))/(ANCLS+1.0)
      CLSTYC(NCUR) =(ANCLS*CLSTYC(NCUR) +Y(II))/(ANCLS+1.0)
      NCLST(NCUR) =NCLST(NCUR) +1
500   CONTINUE
      IF(II.LT.NPTS) GO TO 10
      GO TO 600
C
C     IF THE NUMBER OF THE CLUSTERS
330   THRESH=THRESH*1.2
      GO TO 20
600   CONTINUE
      WRITE(22;41)
      DO 700 I=1;200
      WRITE(22;51)I;X(I);Y(I);CLSTXC(TAG(I));CLSTYC(TAG(I));TAG(I)
700   CONTINUE
      WRITE(22;92)
      DO 450 L =1;NCL
      WRITE(22;91)L;CLSTXC(L);CLSTYC(L);NCLST(L)
450   CONTINUE
320   WRITE(22;31)NCL;THRESH
      DO 400 I=1;NCL
      WRITE (22;61)I;NCLST(I)
400   CONTINUE
      CALL PLOT(NPTS;NCL;X;Y;TAG)
 61   FORMAT(/;10X;'NUMBER OF POINTS IN CLUSTER ';I3;' IS - ';I4)
 31   FORMAT(///;10X;'NUMBER OF CLUSTER INTHE DATA AFTER MODE
      1 SEEKING = ';I2;//;10X;'THE THRESHOLD DISTANCE - ';F12.6)
 41   FORMAT(//;8X;70(1H-);//;10X;'Sample No.';3X;'    X      ' ;3X;
      1'Y      ';8X;'CLUSTER  CENTRE ';3X;'CLUSTER';//;8X;70(1H-))
 51   FORMAT(12X;I4;5X;F8.2;3X;F8.2;3X;F8.3;3X;F8.3;5X;I4)
 11   FORMAT(///;15X;'RESULTS OF MODE SEEKING ANALYSIS';/;8X;70(1H_);/
      1 ;10X;'NUMBER
      1 OF CLUSTERS ALLOWED - ';I4;/;10X;/;10X;' TOTAL NUMBERS OF
      1 SAMPLES = ';I4;/;17X;'THRESHOLD DISTANCE - ';F12.8;/)
 92   FORMAT(//;8X;70(1H-);//;35X;'CENTRE';/;10X;'CLUSTER';7X;'
      1X    ';3X;'      Y     ';6X;'MEMBERSHIP';/)
 91   FORMAT(10X;I4;5X;F12.6;4X;F12.6;8X;I4)
      STOP
      CALL UERTST
      CALL USMNMX
      END
C
      REAL FUNCTION DIST(X1;Y1;X2;Y2)
C     THIS FUNCTION CALCULATES THE EUCLIDEAN DISTANCE
C     BETWEEN TWO POINTS
C     ***********************************************
C
      DIST -SQRT((X1-X2)**2 + (Y1-Y2)**2)
      RETURN
      END
C
C     ***********************************************
      SUBROUTINE PLOT(NPTS;NCL;X;Y;TAG)
C     ---------------------------------
C
C     THIS SUBROUTINE PLOTS THE POINTS IN A TWO DIMENSIONAL PLANE
```

```
C        WITH THE APPROPRIATE TAGS DENOTING THE CLUSTER MEMBESHIP
C        USPLX - IS A LIBRARY ROUTINE USED FOR PLOTTING A GRAPH
C        ---------------------------------------------------------------
         DIMENSION X(NPTS),Y(NPTS),YY(200,4),IMAG4(5151)
         INTEGER TAG(NPTS),A(144)
         READ(24,77)A
77       FORMAT(144A1)
         DO 100 J-1,NCL
         DO 100 I-1,NPTS
100      YY(I,J) -0.0
         DO 700 J -1,NCL
         DO 700 I -1,NPTS
         IF(TAG(I).EQ.J)  YY(I,J) =Y(I)
700      CONTINUE
         IA -NPTS
         INC -1
         CALL USPLH(X,YY,NPTS,4,INC,IA,A,IMAG4,IER)
         TYPE *, IER
         RETURN
         END
```

```
 40     CONTINUE
        DO 50 I=1,4
        DO 50 J=1,10
        WVAR(I)=WVAR(I)+((W(J,I)-WMEAN(I))**2)/N
        BVAR(I)=BVAR(I)+((B(J,I)-BMEAN(I))**2)/N
        VVAR(I)=VVAR(I)+((V(J,I)-VMEAN(I))**2)/N
        RVAR(I)=RVAR(I)+((R(J,I)-RMEAN(I))**2)/N
 50     CONTINUE
        WRITE(22,301)
301     FORMAT(10X,'FEATURE: WATER')
        WRITE(22,777)
777     FORMAT(8X,18('-'),/)
        WRITE(22,302)
302     FORMAT(10X,36('-'))
        WRITE(22,303)
303     FORMAT(12X,'BAND',5X,'MEAN',11X,'VARIANCE',2X)
        WRITE(22,302)
        DO 304 I=1,4
        WRITE(22,305) I,WMEAN(I),WVAR(I)
305     FORMAT(14X,I2,2(3X,F10.4))
304     CONTINUE
        WRITE(22,302)
        WRITE(22,306)
306     FORMAT(10X,'FEATURE: BUILT UP AREA')
        WRITE(22,777)
        WRITE(22,302)
        WRITE(22,303)
        WRITE(22,302)
        DO 307 I=1,4
        WRITE(22,305) I,BMEAN(I),BVAR(I)
        WRITE(22,777)
307     CONTINUE
        WRITE(22,302)
        WRITE(22,308)
308     FORMAT(10X,'FEATURE: VEGETATION')
        WRITE(22,777)
        WRITE(22,302)
        WRITE(22,303)
        WRITE(22,302)
        DO 309 I=1,4
        WRITE(22,305) I,VMEAN(I),VVAR(I)
309     CONTINUE

        WRITE(22,302)
        WRITE(22,310)
310     FORMAT(10X,'FEATURE: ROCK')
        WRITE(22,777)
        WRITE(22,302)
        WRITE(22,303)
        WRITE(22,302)
        DO 311 I=1,4
```

```
      WRITE(22,305) I,RMEAN(I),RVAR(I)
311   CONTINUE
      WRITE(22,302)
C     ***************************************************
C     CALCULATION OF COVARIANCES BETWEEN VARIOUS WAVE BANDS
C     OF VARIOUS FEATURES
C     ***************************************************
      DO 60 J=1,10
      COW1W2=COW1W2+((W(J,1)-WMEAN(1))*(W(J,2)-WMEAN(2)))/N
      COW1W3=COW1W3+((W(J,1)-WMEAN(1))*(W(J,3)-WMEAN(3)))/N
      COW1W4=COW1W4+((W(J,1)-WMEAN(1))*(W(J,4)-WMEAN(4)))/N
      COW2W3=COW2W3+((W(J,2)-WMEAN(2))*(W(J,3)-WMEAN(3)))/N
      COW2W4=COW2W4+((W(J,2)-WMEAN(2))*(W(J,4)-WMEAN(4)))/N
      COW3W4=COW3W4+((W(J,3)-WMEAN(3))*(W(J,4)-WMEAN(4)))/N
      COB1B2=COB1B2+((B(J,1)-BMEAN(1))*(B(J,2)-BMEAN(2)))/N
      COB1B3=COB1B3+((B(J,1)-BMEAN(1))*(B(J,3)-BMEAN(3)))/N
      COB1B4=COB1B4+((B(J,1)-BMEAN(1))*(B(J,4)-BMEAN(4)))/N
      COB2B3=COB2B3+((B(J,2)-BMEAN(2))*(B(J,3)-BMEAN(3)))/N
      COB2B4=COB2B4+((B(J,2)-BMEAN(2))*(B(J,4)-BMEAN(4)))/N
      COB3B4=COB3B4+((B(J,3)-BMEAN(3))*(B(J,4)-BMEAN(4)))/N
      COV1V2=COV1V2+((V(J,1)-VMEAN(1))*(V(J,2)-VMEAN(2)))/N
      COV1V3=COV1V3+((V(J,1)-VMEAN(1))*(V(J,3)-VMEAN(3)))/N
      COV1V4=COV1V4+((V(J,1)-VMEAN(1))*(V(J,4)-VMEAN(4)))/N
      COV2V3=COV2V3+((V(J,2)-VMEAN(2))*(V(J,3)-VMEAN(3)))/N
      COV2V4=COV2V4+((V(J,2)-VMEAN(2))*(V(J,4)-VMEAN(4)))/N
      COV3V4=COV3V4+((V(J,3)-VMEAN(3))*(V(J,4)-VMEAN(4)))/N
      COR1R2=COR1R2+((R(J,1)-RMEAN(1))*(R(J,2)-RMEAN(2)))/N
      COR1R3=COR1R3+((R(J,1)-RMEAN(1))*(R(J,3)-RMEAN(3)))/N
      COR1R4=COR1R4+((R(J,1)-RMEAN(1))*(R(J,4)-RMEAN(4)))/N
      COR2R3=COR2R3+((R(J,2)-RMEAN(2))*(R(J,3)-RMEAN(3)))/N
      COR2R4=COR2R4+((R(J,2)-RMEAN(2))*(R(J,4)-RMEAN(4)))/N
      COR3R4=COR3R4+((R(J,3)-RMEAN(3))*(R(J,4)-RMEAN(4)))/N
 60   CONTINUE
C     ***************************************************
C     CALCULATION OF STIFFNESS MATRICES
C     ---------------------------------------------------
      CALL WSTIFF(WVAR,WKMAT)
      CALL MATIN(WKMAT,4,DET)
      CALL BSTIFF(BVAR,BKMAT)
      CALL MATIN(BKMAT,4,DET)
      CALL VSTIFF(VVAR,VKMAT)
      CALL MATIN(VKMAT,4,DET)
      CALL RSTIFF(RVAR,RKMAT)
      CALL MATIN(RKMAT,4,DET)
      WRITE(23,324)
324   FORMAT(10X,'WKMAT')
      WRITE(23,325) ((WKMAT(I,J),J=1,4),I=1,4)
      WRITE(23,326)
326   FORMAT(10X,'BKMAT')
      WRITE(23,325) ((BKMAT(I,J),J=1,4),I=1,4)
      WRITE(23,327)
327   FORMAT(10X,'VKMAT')
      WRITE(23,325) ((VKMAT(I,J),J=1,4),I=1,4)
      WRITE(23,328)
```

```
328     FORMAT(10X,'RKMAT')
        WRITE(23,325) ((RKMAT(I,J),J=1,4),I=1,4)
325     FORMAT(1X,4(F15.6,3X))
C       ---------------------------------------------------------
C       READING THE TEST SAMPLES AND THEIR ANALYSIS
C       *********************************************************
        K-200
        READ(21,*)((Y(I,J),I=1,K),J=1,4)
C       WRITE(24,1000)
C1000    FORMAT(1X,'OBSERVATION SAMPLES')
C       WRITE(24,1001) ((Y(ISA,IRA),IRA=1,4),ISA=1,200)
C1001    FORMAT(1X,4(I4,3X))
        WRITE(24,99)
99      FORMAT(5X,110('-'))
        WRITE(24,100)
100     FORMAT(5X,'SAMPLE NO.',3X,'CLASS NO.',10X,'WU',12X,'BU',
       110X,'VU',14X,'RU',10X,'DECISION')
        WRITE(24,99)
        DO 70 I=1,K
        II-I
        DO 80 J=1,4
        WW(J)=Y(I,J)-WMEAN(J)
        BB(J)=Y(I,J)-BMEAN(J)
        VV(J)=Y(I,J)-VMEAN(J)
        RR(J)=Y(I,J)-RMEAN(J)
80      CONTINUE
        CALL PRODUT(WKMAT,WW,WU)
        CALL PRODUT(BKMAT,BB,BU)
        CALL PRODUT(VKMAT,VV,VU)
        CALL PRODUT(RKMAT,RR,RU)
        IF(II.LE.50) ICLASS=1
        IF(II.GT.50) ICLASS=2
        IF(II.GT.100) ICLASS=3
        IF(II.GT.150) ICLASS=4
        CALL UMINUM(II,ICLASS,WU,BU,VU,RU,IDESI)
70      CONTINUE
        WRITE(24,99)
        STOP
        END
C       *********************************************************
C       SUBROUTINE TO FORMAT A MATRIX WHOSE ELEMENTS ARE INVERSE
C       OF VARIANCES AND COVARIANCES
C       *********************************************************
        SUBROUTINE WSTIFF(WVAR,WKMAT)
        DIMENSION WKMAT(4,4),WVAR(4)
        COMMON/AREA1/COW1W2,COW1W3,COW1W4,COW2W3,COW2W4,COW3W4
        DO 11 I=1,4
        WKMAT(I,I)=WVAR(I)
11      CONTINUE
        WKMAT(1,2)=COW1W2
        WKMAT(2,1)=WKMAT(1,2)
        WKMAT(1,3)=COW1W3
        WKMAT(3,1)=WKMAT(1,3)
        WKMAT(1,4)=COW1W4
```

```
      WKMAT(2,3)=COW2W3
      WKMAT(3,2)=WKMAT(2,3)
      WKMAT(2,4)=COW2W4
      WKMAT(4,2)=WKMAT(2,4)
      WKMAT(3,4)=COW3W4
      WKMAT(4,3)=WKMAT(3,4)
      RETURN
      END
C     ***************************************************************
      SUBROUTINE BSTIFF(BVAR,BKMAT)
      DIMENSION BKMAT(4,4),BVAR(4)
      COMMON/AREA2/COB1B2,COB1B3,COB1B4,COB2B3,COB2B4,COB3B4
      DO 11 I=1,4
      BKMAT(I,I)=BVAR(I)
11    CONTINUE
      BKMAT(1,2)=COB1B2
      BKMAT(2,1)=BKMAT(1,2)
      BKMAT(1,3)=COB1B3
      BKMAT(3,1)=BKMAT(1,3)
      BKMAT(1,4)=COB1B4
      BKMAT(4,1)=BKMAT(1,4)
      BKMAT(2,3)=COB2B3
      BKMAT(3,2)=BKMAT(2,3)
      BKMAT(2,4)=COB2B4
      BKMAT(4,2)=BKMAT(2,4)
      BKMAT(3,4)=COB3B4
      BKMAT(4,3)=BKMAT(3,4)
      RETURN
      END
C     ***************************************************************
      SUBROUTINE VSTIFF(VVAR,VKMAT)
      DIMENSION VKMAT(4,4),VVAR(4)
      COMMON/AREA3/COV1V2,COV1V3,COV1V4,COV2V3,COV2V4,COV3V4
      DO 11 I=1,4
      VKMAT(I,I)=VVAR(I)
11    CONTINUE
      VKMAT(1,2)=COV1V2
      VKMAT(2,1)=VKMAT(1,2)
      VKMAT(1,3)=COV1V3
      VKMAT(3,1)=VKMAT(1,3)
      VKMAT(1,4)=COV1V4
      VKMAT(4,1)=VKMAT(1,4)
      VKMAT(2,3)=COV2V3
      VKMAT(3,2)=VKMAT(2,3)
      VKMAT(2,4)=COV2V4
      VKMAT(4,2)=VKMAT(2,4)
      VKMAT(3,4)=COV3V4
      VKMAT(4,3)=VKMAT(3,4)
      RETURN
      END
C     ***************************************************************
      SUBROUTINE RSTIFF(RVAR,RKMAT)
      DIMENSION RKMAT(4,4),RVAR(4)
```

```
60      CONTINUE
        WRITE(24,100) II,ICLASS,WU,BU,VU,RU,IDESI
100     FORMAT(8X,I3,9X,I2,5X,F13.4,3X,F10.3,5X,F12.4,4X,F13.4,
        112X,I2)
        RETURN
        END
C       ****************************************************
C       SUBROUTINE FOR MATRIX INVERSION
C       ***************************************************
        SUBROUTINE MATIN(A,N,DETERM)
C       A=CO-EFFICIENT OF ORDER N
C       B=VECTOR OF ORDER N
C       M=IF M IS SET TO ZERO,ONLY INVERSEIS COMPUTED
C       DETERM=VALUE OF DETERMENENT RETURNED
C       ------------------------------------------------
        DIMENSION A(4,4),IPIVOT(4),INDEX(4,2)
        EQUIVALENCE (IROW,JROW),(ICOLUM,JCOLUM),(AMAX,T,SWAP)
C       INITIALIZATION
10      DETERM=1.0
15      DO 20 J=1,N
20      IPIVOT(J)=0
C       SEARCH FOR PIVOT ELEMENT
30      DO 550 I=1,N
40      AMAX=0.0
45      DO 105 J=1,N
50      IF(IPIVOT(J)-1)60,105,60
60      DO 100 K=1,N
70      IF(IPIVOT(K)-1)80,100,740
80      IF(AMAX-ABS(A(J,K)))85,100,100
85      IROW=J
90      ICOLUM=K
95      AMAX=ABS(A(J,K))
100     CONTINUE
105     CONTINUE
110     IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
C       INTRECHANGE ROWS TO PUT PIVOT VECTORS ONDIAGONAL
130     IF(IROW-ICOLUM)140,260,140
140     DETERM=-DETERM
150     DO 200 L=1,N
160     SWAP=A(IROW,L)
170     A(IROW,L)=A(ICOLUM,L)
200     A(ICOLUM,L)=SWAP
260     INDEX(I,1)=IROW
270     INDEX(I,2)=ICOLUM
C       DIVIDE PIVOT ROW BY PIVOR ELEMENT
310     PIVOT=A(ICOLUM,ICOLUM)
320     DETERM=DETERM*PIVOT
330     A(ICOLUM,ICOLUM)-1.0
340     DO 350 L=1,N
350     A(ICOLUM,L)=A(ICOLUM,L)/PIVOT
C       REDUCE NON PIVOT ROWS
```

```
380    DO 550 L1=1,N
390    IF(L1-ICOLUM)400,550,400
400    T=A(L1,ICOLUM)
420    A(L1,ICOLUM)=0.0
430    DO 450 L=1,N
450    A(L1,L)=A(L1,L)-A(ICOLUM,L)*T
550    CONTINUE
C      INTERCHANGE THE COLUMNS
600    DO 710 I=1,N
610    L-N+1-I
620    IF(INDEX(L,1)-INDEX(L,2))630,710,630
630    JROW-INDEX(L,1)
640    JCOLUM-INDEX(L,2)
650    DO 705 K=1,N
660    SAP=A(K,JROW)
670    A(K,JROW)=A(K,JCOLUM)
700    A(K,JCOLUM)=SWAP
705    CONTINUE
710    CONTINUE
       DO 11 K=1,N
       IF(IPIVOT(K).NE.1)GO TO 12
 11    CONTINUE
       RETURN
 12    WRITE(22,991)
 991   FORMAT(/30X,'MATRIX IS SINGULAR'/)
 740   RETURN
       END
 C     *************************************************
 C     ***************************************************
```